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GEOGRAPHY FIELD WORK AT JUNIOR HIGH SCHOOL LEVEL[1]

BY EDNA E. EISEN
Steuben Jr. High School, Milwaukee, Wisconsin

In any school activity the contribution which that activity makes toward reaching the goal or major objective of general education must be considered. Therefore we ask, "What can geography field work at the junior high school level contribute toward the goal of general education?" Since the major objective of general education may be stated as "Ability to cope effectively with everyday problems of living, vocational, avocational, social, and civic" and since "Right social and civic attitudes which hinge on sound, well rounded perspective" are attributes essential to the realization of this major objective, let us see how *experiences* which boys and girls of junior high school age have had on geography field trips help in the attainment of this major objective.

Geographers speak of two kinds of field work, the reconnaissance survey type and the intensive or detailed field survey type. In the first, large areas are surveyed with the purpose of obtaining, in a general way, the pattern of land utilization in relation to the natural environment. In the second, a much smaller area is considered in order to secure accurate and specific data of land utilization and associated facts of the natural environment. In most of our leading colleges and universities field courses of one or both of these types just described are given as part of the geography curriculum. Most of the students in such

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[1] This paper was presented before the geography section of the Wisconsin Teachers Association at their meeting in November, 1932.

courses, however, are beyond the level of general education and are probably specializing in the field of geography. It seemed that in order to reach the goal of general education that students at a lower level, even as low as the junior high school, should not be deprived of similar experiences in the field which give insights into relationships between man and his natural environment. In order to try out the possibilities of field work at the junior high school level, a geography club was organized in September, 1929. The first year the club membership was limited, as it was felt that twenty-five was about the maximum number that one teacher could conduct comfortably and profitably on a trip. Since then, however, in order to conform with the exploratory principle of the junior high school, membership has been open. In 1932–33 the club had enrolled 200 members, pupils of the seventh, eighth, and ninth grades, and there were 75 boys and girls on our trip the first Saturday in October. By an arrangement of small groups under capable leaders (boys who had been members of the club for two years) even so large a number gained profitable experience. Although our trips have not been definitely reconnaissance survey or detailed survey types, it will be our purpose to describe what we have done in both urban and rural field work and to point out why we feel that our junior high school pupils have gained worthwhile geographic experiences which contribute toward the goal of general education.

The aim of the urban field work is to gain an understanding of the layout of the city and the function of its various parts in relation to natural factors. In order to arrive at such an understanding there are many concepts and simple relationships which must be acquired first. Since a map is a useful tool in acquiring geographic understandings, it is necessary that pupils who are to participate in field work have the ability to express their findings in map language and also to use a map properly in the field. For these reasons map reading and a scheme to be used in mapping land utilization are problems at a meeting before going into the field. Each child is supplied with a street map of the city and shown how to orient his map. The various uses of land in the city, such as houses, flats, apartment buildings, hotels, grocery stores, meat markets, department stores, office buildings, garages, theaters, foundries, factories, schools, churches, golf courses, parks, and others are listed. The pupils see the impossibility of attempting to show each of these very

specific uses of city land on their small scale maps (about 1 inch to a mile) or even on the larger scale city map (4.4 inches to a mile) which we have posted. The task of mapping is fairly simple, however, if these many specific uses are grouped into five or six classes or types of land utilization found in the city. Houses, flats, apartment buildings belong to the residential group which are to be indicated on the map in orange. The various kinds of stores and all places that sell service, including coal and lumber yards, grain elevators, warehouses, terminals, etc. are classed as commercial and are colored in red. Machine shops, foundries, and factories belong to the manufactural group and are designated by purple. Yellow is used to indicate schools, libraries, churches, hospitals, and other social uses. Playgrounds, parks, golf courses, and recreational uses are shown in green. Since the base map used by the pupils is one supplied us by the Milwaukee Electric Railway and Light Company and has all land transportation routes indicated, we soon discarded our first plan of denoting street car lines by solid red lines and railroads by broken red lines. Mimeographed copies of the map legend are supplied each child for the inside cover of his notebook. In order that the children may be able to use this scheme of mapping in the field, they are given some simple practice. Each child makes a drawing of a city block, indicating both sides of the street. The north-south distance is drawn longer than the east-west distance, but no attention is given to scale of miles. The pupils are taken out to map a block near the school. On the trip around that block, three of the major types of land uses are found, residential, social, and commercial and some vacant land. The question arises of how to map a street where most of the block is in stores but on which there are two residences. It is decided to map such a block as commercial since that is the dominant use and to follow that procedure in all similar cases. This experience is helpful in understanding that maps show generalizations.

This introduction to mapping is followed by individual assignments of small areas in the vicinity of the school on simple base maps drawn by the pupils. In 1932–33 a slightly different procedure was tried. Since our school building is located on a particularly high site, after the idea of mapping had been presented, the children were taken out on the roof of the building to note the various types of land utilization which they could see. In fact they were able to note some forms of all types of city land

use from that vantage point. A mimeographed map of the street pattern of the area had been prepared, and the pupils were given these to use for their individual assignments. In both cases the field maps, as well as all future field maps, are turned into the committee who check the findings and transfer them to the land utilization map of the city. With this simple training in mapping the boys and girls have a helpful tool to use in the field. We have tried three kinds of maps in the field itself; first a simple street pattern sketch made by each pupil before the trip; next mimeographed maps of the area to be traversed; and this year, we are trying a number system to designate each of the major land uses directly on the small scale city map on which the route is followed.

Urban field trips are planned to familiarize the boys and girls with the important commercial and manufactural activities of the city; to learn what activities of these classes are carried on in the city; to see how they are carried on; and to try to find reasons why they are carried on where they are and in the ways they are.

An understanding of the activities and layout of the port of our city is our first objective. It requires several trips to do this. The first one is usually to the harbor entrance. To reach the entrance a traverse is made from the downtown retail store district, into the wholesale and jobbing sections, past establishments carrying on light manufacturing, and finally to the warehouses and storage plants along the Milwaukee River. The boys and girls note the changes in land utilization. The pupils are taken out to the old lighthouse at the entrance to the harbor where there are many things to be learned. From here we note the breakwaters which enclose the outer basin or harbor of refuge. The children inquire about the use of this outer harbor and learn that it is little used by vessels seeking shelter from storms, but, at times, on account of congestion it is used by vessels awaiting an opportunity to enter the inner harbor. In 1932 a dredge was at work south of the entrance channel on the project which proposes to have the main terminals on the lake front.[2] The sewage disposal plant across on old Jones Island and the incinerator are noted and reasons for locating these here are

[2] In 1933 when this part of the harbor was visited, the municipal transit shed on the north side of the first slip was found completed and men were at work hauling bales of imported wood pulp from the shed to the railroad cars for shipment to the paper mills of the Fox River Valley. On the south side of the slip there were piles of iron scrap which we were informed would help fill vessels returning to the steel mills.

discussed. The fact that this harbor entrance is at the confluence of the Kinnickinnic and the combined Milwaukee and Menominee Rivers which unite to form a common outlet is explained. Uses of the lands fronting these waterways which can be seen from our position on the north pier are the municipal open dock and the municipal car ferry slip and railroad tracks on Jones Island, grain elevators, oil tanks, railroads and yards, and coal-handling terminals and yards where commonly a coal boat is being unloaded. North of the entrance the level stretch of newly made land used as an airport is noted, the railroad yards and terminal and beyond that the view indicates a change from the commercial usage. A lovely parkway and drive, high class apartment hotels, and fine residences are a decided contrast to what is seen in the immediate area. How did this happen is asked? Why don't the big boats dock along the waterfront? The children are asked if they notice any difference in the kind of land in the two sections. Yes, that to the north of the depot is flat only a short distance in from the lake front where the parkway is and all the buildings are at the top of the bluff while in the commercial district the land is all very low. The children are told that the level land to the north is mostly all newly made land and that formerly the railroad tracks of the Northwestern line occupied the only low land between the bluff and the lake; and that they have found one fact which helps to answer their question and that most of the area along the lower river courses was once a marsh and not desirable for residential purposes. Of course, before the building of the breakwaters the open lake front did not offer the port facilities which the rivers, Kinnickinnic to the south, Milwaukee to the north, and Menominee to the west did for commercial development. Before investigating a part of this inner harbor the children have one of their most fascinating experiences, namely, to watch a large lake carrier being towed into port. The question of why the tug is used arises. The children are informed that the use of tugboats is not required by law, but due to narrow and torturous channels and the large number of bridges with narrow openings, vessels generally employ tugboats with pilots familiar with the course. From their position on the pier the children usually are able to make the captain hear these questions: "What is your cargo? Where do you come from? Where are you going to dock?" It is not surprising to learn that the cargo is coal, which makes up about 85 per cent of the total port receipts. On one trip it was learned that the

huge boat was bringing to our coal-less state anthracite which had been sent by rail from the mines in eastern Pennsylvania to a Lake Erie port and there had been transferred to this carrier for shipment on the Great Lakes. In 1932 the boat we watched was carrying 7000 tons of soft coal which it had taken on at Sandusky, Ohio. It was headed for the coal yards up the Menominee River which could not be seen from our position.

The return traverse offers opportunities for a study of the inner harbor facilities. Along the street side at the large storage warehouses men are usually at work either loading or unloading trucks with the commodities carried by the freight boats which dock on the river side. Celery and baskets of grapes from Michigan were being loaded on trucks on one of our trips. As the route is continued, the children observe several kinds of factories and the low class residences in the area. On a recent trip we were fortunate to find one of the largest freight boats on the lakes docked at a warehouse on the right bank of the river and the coal boat which we had watched coming into port tied up at a warehouse terminal on the left bank. Upon inquiring why the coal boat had not moved on, we learned that its way was blocked by the freighter. Men were rushing to unload from the latter bags of sugar which we were rather surprised to learn was Hawaiian sugar, refined and bagged in San Francisco, shipped via the Panama Canal to New York, sent to Buffalo from where it had been carried here. The fortunate part of this experience was seeing how the freight boat was moved up the Milwaukee River to give the coal boat room to make the turn necessary before it could go through the swivel bridge and on up the Menominee River where it was to dock. One after another of the children remarked somewhat like this, "I suppose that is one of the reasons why they want to build piers and docks at the outer harbor."

There is another type of shipping which can be seen in this section of the commercial district on the return traverse. One of the Pere Marquette Line packets is to be found in dock during the day throughout the year, since these boats which only cross Lake Michigan do not have to stop running from December to April as do those which are engaged in interlake traffic which is blocked by ice conditions at the Straits of Mackinac, the entrance to Lake Michigan. The children consider it a rare treat to be taken aboard one of these boats, at the close of the trip.

In order to understand the problem of the port facilities at least three other trips are necessary.

The upper Kinnickinnic River district, or the south end of the inner harbor, furnishes a great many new ideas. On the route a manufacturing district is observed in which there are various kinds of heavier types of manufacturing establishments, among which is the wreckage of smelters of a former iron and steel industry. The children wonder why that industry is no longer carried on here since this location seems to have the advantage of both water and rail transportation. They are surprised to learn that practically no iron ore comes into our port since the development of the very large scale iron and steel industry in the Chicago district from which the factories here receive pig iron, steel, ingots, etc. for fabrication. One of the uses of the great amount of coal received at the port is seen at the coke and gas plant. At one of the car ferry terminals the children learn of the advantages of using this type of carrier. They see the loaded freight cars move directly onto the monstrous craft. They are told that these carferries, which operate throughout the year, are of vast importance to Milwaukee industries, as they represent the main factor in keeping Milwaukee on the Chicago basis of rates to and from eastern ports. Trains using the carferry route avoid the congestion in the Chicago district and so there is a saving of both time and money. The carferries which operate daily between Milwaukee and Michigan ports handle between 25 and 30 per cent of the total lake commerce of the port. Another opportunity on a trip in this area is to learn how grain is handled at the Kinnickinnic elevator. We have been fortunate to arrive at a time when corn from Iowa had just been transferred from the cars in the rear to the elevator at the rate of 16,000 bushels per hour and was being transferred from the elevator to a large lake carrier at the rate of 60,000 bushels per hours, for shipment to Buffalo for use in manufacture of various corn products. The traverse may be continued from here to the south end of old "Jones Island" and end up at the sewage disposal plant on the other side of the harbor entrance where the previous trip had begun. Here the work of dredges, pile driving apparatus, sand suction machinery which are used in harbor improvements may be observed. On the Kinnickinnic side one is very likely to find several large lake carriers using the basin for winter quarters, the rent from which helps to pay the upkeep of the port.

A trip to the Menominee Valley coal district shows how the port spreads to the west side of the city. Much of the area may be surveyed from the viaducts. In fall and winter the pupils see the docks and yards piled high with coal of various kinds and sizes. Up to December they may see the apparatus at work unloading the coal from the large lake carriers. Later, however, the slips are usually occupied by carriers left to winter there. Trucks and cars are loaded with coal for distribution in other parts of the city and for transhipment to the north and west by rail. The railroad yards, factories, gas tanks, and other forms of occupance which are located in the valley are noted. We have been here on days when the temperatures were close to 0°F. and after the general survey have visited the gas plant. Although our object is not to learn the process of producing gas, it is worthwhile to find out how by the use of a type of retort oven many by-products are saved and marketed. On a trip to this area in May the children are astonished to find that many of the empty carriers have not left their winter quarters. The children learn that the owners are waiting to obtain a return cargo and that often this is difficult. Of course they ask why. It isn't hard to understand that it is a problem when they are told that the average total receipts for the ten year period, 1920–1929, exclusive of car ferry traffic, amounted to over 4,000,000 tons, while the total shipments for the same period were under 700,000 tons, of which grain was 75 per cent.

From the top of the reservoir hill a splendid reconnaissance of the upper Milwaukee River section may be made, where the change from strictly commercial and manufactural use of the valley to a recreational and residential use with some manufacturing is noted. Time does not permit going into detail of the occupance forms, coal docks and coal yards, tanneries, lumber yards and planing mill, and various kinds of manufacturing which are noted on the traverse from the north limit of commercial utilization of the river to the heart of the city, but this trip completes a study of the layout and activities of the port.

In gaining this understanding, the surrounding manufacturing industries always have been studied with a view of finding out principally what goes in and what comes out of the factories. It is easy for the children to realize that as the city grew the growing manufacturing industries could not keep within the commercial district. In order to understand where other manu-

facturing districts are located several trips are taken. Since the manufactural pattern of our city is quite closely tied to the courses of the three rivers and the railroads which, in general, follow these valleys, traverses are made of the areas beyond where the rivers are used commercially. On the traverse up the Milwaukee River paper and box factories, a large iron works, and a few other manufactural industries are noted, although parks and residences occupy most of the river bluffs. However, west of the river and following rather closely a railroad route are found numerous large plants which, in normal times employ many of the people living in the district. Although the homes are not pretentious, the children observe how much better kept these homes of the factory workers are than those in the harbor district. Among the kinds of factories seen are several making electrical equipment, automobile bodies, bridge and iron work, automobile frames, pipes, and others. In order to find out about the raw materials used and how they are obtained and how the manufactured product is distributed we have at times visited a plant. On the whole, we do not feel that the time spent in watching processes is worthwhile. One idea which the children were impressed with on one visit was how mechanical devices have been improved to minimize the amount of human labor needed. The manufacturing district in the Menominee Valley, likewise crossed by railroad lines, includes several kinds of large scale industries, one of the largest being the motorcycle factory. Similarly on the south side of the city and beyond into the suburbs to the south and west is found a manufacturing area. Among the kinds of factories of special note are the machine shops and foundries, metal works, tire, and chemical plants. With these main manufactural districts fitted into the map, it is relatively easy to join these together with the residential districts and the retail commercial districts and parks, so that the children understand the structure of their city.

In a city of the size of this one the opportunities for rural field work are somewhat limited because of the expense involved in transportation far enough into the country to get away from subdivision projects. Our purpose in the rural work has been to familiarize the children with some farm activities, to have them see simple relationships between land occupance and associated forms in the natural environment, and to build up a sympathetic feeling and respect for the work of the people outside of the city. We have had two kinds of rural trips, both of which we feel

accomplished our purpose at least in part. On the one we made a traverse along country roads. At a meeting before the trip we talked over what we would look for and the children helped to make a form sheet on which to note the things they found. Among the items listed the following is a fair sample: uses of different kinds of land, the level, the gentle slopes, the hilly, and that along streams; the kinds of soil; the kinds of crops seen and the stage of their growth; the kinds of work the farmers are doing at the time—plowing, disking, harrowing, seeding, cultivating, harvesting, etc.; the kinds of livestock and where they are kept; orchards; farmsteads and farmyards and buildings. We have usually stopped to make a rough sketch map of at least one farm layout and to talk with the farmer about his work, the calendar of his farm operations, the marketing of his crops, etc. On the other type of rural trip we charter a bus and arrange for several stops at places where the children may see different kinds of land utilization. A recent trip of this sort into Waukesha County proved very worth while. The children were instructed to study the landscape en route, and many asked questions about things they saw. Our first stop was at a large truck farm. The owner very kindly answered our questions so that the children learned several reasons why this land was used for a truck farm. The black soil they saw was peat soil, drained from swamp land by tiling, and does not lend itself to the type of farming found on the slopes and higher lands where the soil is very different. Furthermore, this location near the city makes trucking of products to market relatively simple and also helps to solve the labor problem. During the four or five months of marketing fifty workers are employed on these 100 acres of flat land. The children saw the men at work in the sheds and appreciate something of the work attached to trimming, washing, tying, and packing radishes, carrots, and celery for market. They learned that these soils need to be tested and fertilized every spring to be productive. In the fields they saw the overhead system of irrigation that is needed to supply the vegetables with enough water during the hot summers, even though the average annual rainfall in our state is over thirty inches, these plants would burn up from the hot sun. Our next stop was at a fox farm which afforded a novel experience for all. The children enjoyed seeing how the foxes are housed and learning a little from the owners about the problems of raising these animals and marketing the pelts. The owner told us that he selected this site

for two reasons, (1) the south slope cleared of snow quicker in the spring and (2) the woods offered shade. Along the route the children realized that they were in a section of many dairy farms by the barns and silos and the various kinds of cows seen in the pasture. They noted the rolling hill country and the slopes and woodlands strewn with boulders, signs of the glacier. However, the visit to a large scale dairy farm on which all of the 400 cows of various breeds are kept in the barns and fed scientifically on a diet of silage and hay and grain produced on this and near-by tenant farms gave the feeling of factory farming. The children saw the bottled milk loaded on to the refrigerator cars which would carry it to the Chicago market. How very different was the 80 acre neighboring farm where the farmer in order to have some income besides that derived from his 30 cows has gone into the raising of turkeys. Although not strictly of the country, a visit to a limestone quarry was our last stop on the return trip. The children saw how the steam shovels pick up the pieces of blasted stone in their giant claws to load the waiting cars. These rural trips did not permit detail study, nevertheless, it is felt that the children have gained profitable experiences.

It has been our purpose to describe the sorts of things we have been able to do in field work as an extra-curricular activity. Now, in conclusion, may we sum up the contributions we feel these activities make in helping the pupils attain the ability to cope effectively with every day problems of living, vocational, avocational, social, and civic. The boys and girls participating in the work possess certain ideas about their city as a whole. They gain an understanding of the relation of the shape, street pattern, and land utilization pattern of their city to its site through acquiring many concepts and simple relationships. Although we do not presume that these children are equipped to solve all problems of use, we do feel that they appreciate certain problems and that they realize the magnitude of these problems which the average citizen is so apt to attempt to solve from a priori reasoning. For example, the experiences which these boys and girls have had in the study of the port facilities have opened their eyes to questions concerning the improvements of the harbor at enormous expenditures to accommodate larger ocean going vessels and to the whole question of the advisability of the Great Lakes Waterway. Again, may we repeat, we do not say that the children have the ability to answer these questions, but they have the perspective which may give them the correct

inquiring civic attitude toward the problem in the future. They have pride in their city, but not a false pride, for they have seen its disadvantages as well as its advantages. They have seen various possibilities for a selection of a vocation which they may desire to follow. Their appreciation for the work of people in industry will help to develop proper social attitudes as well as civic. For example, the realization of the inferior living conditions in certain sections of our city may help to instill in these boys and girls a desire for their improvement. Likewise, in the country the boys and girls in acquiring the many concepts and relationships have an understanding which may help them to appreciate such problems as farm relief. In the country and also in the city the children learn to enjoy beauty. For example, many remarked with great pleasure in seeing a flock of sheep grazing on a wooded hill slope along the country road. Our superb waterfront never fails to receive praise. Such training will help to make boys and girls anxious to see other places and to know what to look for. It is very doubtful whether any of these pupils would do as a certain doctor and his daughter did in traveling by rail up the Rhine—"read detective stories because there wasn't anything to see anyway." In addition, the concepts and relationships gained in this direct way are a great help to the children in understanding land occupance in other regions. For example, two pupils recently reported on cities, the one on Cape Town, the other on Durban. The first gave an encyclopedic enumeration of facts about the city, which was dry and uninteresting, and gave no feeling of the personality of Cape Town. The second, a girl who has belonged to the geography club for a year, went to the board, drew a rough sketch map and showed as well as she could from the material she had available where the commercial district was and what might be seen there, and where the residential and recreational districts had developed and explained why. She gave her audience an idea of what Durban is like.

Therefore, it is believed that these children equipped with an understanding of their own community are better able to understand the personalities of other regions studied and all in all are better able to cope effectively with everyday problems of living, vocational, avocational, social, and civic and so, our junior high school field work does, in its own way, make its contribution toward the goal of general education.

HAS MATHEMATICS VALUE FOR EVERY HIGH SCHOOL PUPIL?

By Virgil S. Mallory
State Teachers College, Montclair, New Jersey

This question is a broad one and a complete answer to it is beyond the limits of this paper. Its answer is contained in the personality and interests of the particular teacher who is teaching the mathematics, it is contained in the type of mathematics that he teaches, and the method that he employs in teaching it. It reaches to the objectives and ideals of the American secondary school with its insistence on a high school education for everyone. It is affected particularly at this time by the non-selective character of our high school population. It is colored by the generality of the objectives of the secondary school—the purposeful and specific denial of specialization and of definite preparation for a trade or profession. It is necessary to limit the question by defining its terms.

The question refers to *all* the pupils in high school. Probably it will be admitted that those pupils who are particularly brilliant in mathematics receive value from the mathematical courses they take. It will be sufficient therefore, to refer the question to the large number of pupils who cannot be classified as having "mathematical minds"—whatever that may be. To-day this pupil is entering our high schools in ever increasing numbers. If this pupil finds difficulty in doing quantitative thinking, if he has no conception of logical reasoning, if he cannot see and has no interest in the relations and ratios, the dependence and functionality of the every day world, if he is inaccurate and does not appreciate the value of precision in language and in work, then he needs the kind of training that mathematics can give him. This is contrary to the generally accepted theory that unless one displays by a prognostic test or otherwise that he can succeed in mathematics without too much effort on the part of the teacher, he has no place in the mathematics class room.

In speaking of the values that the pupil can receive from his high school training one must have in mind more than improvement in that arithmetic which every one admits is useful, skill in computation. There are unmeasurable and intangible values which come to him in developed appreciations, in correct habit formation, and in improved attitudes toward work and study. We no longer believe that mental exercise whatever its nature,

develops the intellect and in some subtle way transfers into useful procedures. However it seems reasonable to believe that directing the pupil in ways of deliberate careful thinking, pointing out the beauty of accuracy and precision, directing the attention to examples of variation and dependence, showing the beauty of order and symmetry in nature,—that these influences will make valuable contributions to the education of the child not so well obtained in any other subject matter field. Thus at this time we need not stress as an important part of his education the pupil's ability to factor, to perform problems in long division, to extract square root, or to pass set examinations, although these may or may not be incidental parts of the training he receives. In obtaining the benefit of these values for the child it is known that the fullest success will only be obtained if his interest can be aroused and his cooperation obtained. Thus we have the importance of the teacher's personality and of the richness of the teacher's background material.

In seeking to determine whether the study of mathematics can have value for every pupil it is also necessary to consider what kind of mathematics we have in mind and how it is to be taught. It is perfectly possible for a pupil to be able to factor the quadratic trinomial with great facility and still derive little of value from his ability to do so. Repeating perfectly a memorized proof in geometry does not necessarily mean that the pupil has any appreciation of logical proof or that he is developing the habit of careful and precise statement. Professor Gunther of Stevens Institute of Technology said some years ago that the pupil would obtain more education by memorizing parts of Shakespere than in repeating geometric statements however perfectly, that he does not understand and appreciate.

In a class visited recently the practice teacher drew a quadrilateral on the board and asked the class the number of degrees in its angles. Helpful brighteyed Jean volunteered. "$n-2$" she said. Then apologetically, "It's really 360°, but you have to say $n-2$." It is possible that we do not fully appreciate the psychology of the Jeans we have in our classes: that we have not fully convinced them of the reality of the mathematics they study. They come to think that there is a certain abracadabra about it all; a set of teachers' rules and laws to follow; a sort of Alice in Wonderland world where things don't make sense. There is perhaps too much consideration of imaginary things and too little measuring the height of real flag poles. Too much

repetition of geometric proof and too little appreciation of logic in every day reasoning. For it is surprising how well a class can solve set book problems after they have mastered the technique and how miserably they handle the same problems set in real situations. The boy who gave .84567 gal. as the capacity of the cylindrical tank 6 feet in diameter and 4 feet deep evidently had some facility in the use of skills: it is doubtful if he showed as much mathematical sense as the boy who found "about 800 gal." Certainly the first boy never visualized the relation between the size of the tank and a gallon container. The atmosphere of the class room, and the reality of its problems thus determine to a large extent the value the child will get from his study of mathematics.

Different methods of conducting the class period emphasize different values for the child. Thus the contract plan among other things should help to make him a self-starter. The supervised study period teaches him how to make economic use of his time in studying. Both plans are admirably suited to drill and practice work. While these are important values that he should get from the study of mathematics there are other values which can be better obtained in other ways.

The National Committee on the Reorganization of Mathematics in 1923 did not think that 9th year mathematics should be a series of loosely connected skills, success in which depended largely on drill. For they say: "Drill in algebraic manipulation should be limited to those processes and to the degree of complexity required for a thorough understanding of principles and for probable applications in common life or in subsequent courses which a *substantial proportion* of the pupils will take. It must be conceived throughout as a means to an end, not as an end in itself." (Page 11.) Thus the exclusive or predominant use of any one method of teaching does not give the fullest opportunity for the development of the child's thinking under capable leadership. If mathematics is mainly drilling to perfect certain skills, if it is largely practicing the same operation over and over, if it has little to do with thought, then it can be learned like a trade and needs no more subtle method.

One of the most important activities of the class room is the discussion by the pupils under the direction of the teacher of the mathematics they are studying. This ability to lead the pupils to think quantitatively, to examine a problem from all sides, to consider its applications in and its implications for real

life seems to be one of the most important functions of the teacher. To quote the National Committee again: "Whereas there can be little doubt about the small value to the student who does not go on to higher studies of some of the manipulative processes criticized by the National Committee, there can be no doubt at all of the value to all persons of any increase in their ability to see and to foresee the manner in which related quantities affect each other." (Page 65.)

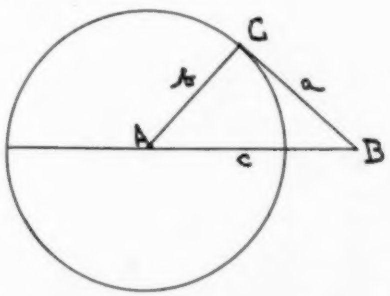
This study of the idea of relationships between quantities calls for much more skillful teaching and direction from the teacher than the mere manipulation of symbols. It is important because "such relationships do occur in real life in connection with practically all of the quantities with which we are called upon to deal in practice." It is possible for the teacher to unify the entire course in secondary school mathematics by having a philosophy that recognizes the necessary balance between the development of manipulative skills and the development of careful and thoughtful appreciation by the pupil of the reality of the situations he studies and of the applications of relationships in the changing world about him. Frequently a careful consideration of the different situations arising by changing a variable in a single problem is worth more to the class than working dozens of problems that follow a set procedure. Of course the graph is the easiest way to study dependence, and the graph should be used throughout the junior and senior high school course to illustrate changing values. To quote the National Committee: "After the necessary technique has been adequately presented graphic representation should not be considered as a separate topic but should be used throughout, wherever helpful, as an illustrative and interpretative instrument." (Page 23.)

Thus, if iron weighs 490 lb. to the cubic foot, the weight w in pounds of a spherical shot d inches in diameter is $w=.14d^3$. Plotting this formula is a valuable laboratory exercise for a 9th grade class and it is not too difficult for an 8th grade class. The discussion of the graph is more important than the plotting, for from it can be found not only the weight of shot of different diameters, but the diameter of a shot which weighs 8 lb., or 10 lb., or 16 lb., and from this is evident the change in the weight as the diameter changes. In the same grade graphical representation of the paths of trucks and cars which run between two cities, with varying speeds and starting times and with stops for

lunch and repairs give an opportunity for the solution of problems and for the discussion of the relationships between d, r, and t when one of them is fixed and the other two vary.

In studying the circle and the relationships between the radius and the circumference and the radius and the area, what happens to the circumference when 1 in. is added to the radius? Of course the boy who runs 3 feet from the edge of a circular track or a track with straight sides and semicircular ends runs farther than the boy who runs on the edge. How much farther? Do the dimensions of the track make a difference in the extra distance that he runs? How is the circumference of a circle changed by adding a feet to its radius? How is the area changed? How is the area of a square changed by adding a feet to each side? Draw a rectangle with sides l and w and another with sides $l+a$ and $w+b$. How do they differ? What extra areas are added? If two cylinders each have altitude h and radii x and $x+a$ respectively, how do they differ? Is their difference equal to a cylinder with a radius a? If the area of a rectangle is constant (12 sq. in.) and its dimensions are l and w, what does the width become if the length is $\frac{2}{3}l$?

In geometry the opportunities for studying relationships are fully as great. In the figure $a^2=b^2+c^2-2b'c$. How does a^2 change as C moves about the circle? When is $a^2=b^2+c^2$? How does it approach $(b+c)^2$? $(c-b)^2$?



The change in the length of common internal or external tangents as the line of centers changes, the measure of angles formed by chords or secants or tangents to a circle, the extension of the Pythagorean theorem to similar polygons with n sides as n increases, Pappus' theorem about the relation between the parallelograms constructed on the sides of a triangle, particularly of an isosceles triangle as the vertex angle changes, all of these offer excellent opportunities to stress dependence. The

most fertile field in geometry is perhaps the study of locus. Particularly is this true if it is studied as the path of a moving point and if at the beginning the pupil can be freed from the onus of remembering what he has to prove.

Actual examples of loci are needed to lend reality to the picture whether it be the parabola made by a thrown piece of chalk, the straight line of the center of a wheel rolled along the floor, the cycloid made by the paper fastened to the rim of a hoop rolled along the chalk rail, or the cardiod in the cup of coffee moved about under a light.

To carry the illustration to other topics is unnecessary. To have children learn we must bring our teaching within their comprehension. If our mathematics is more than skillful manipulation, if it is to teach pupils to think independently, we must use whatever activities we can to enable them to make the connection between the material they study and real life situations. It seems to me that if we remember more frequently that we are teachers of children and less frequently that we are teachers of mathematics that we will give our pupils more of the real value that can be derived from the study of mathematics.

SECOND AMERICAN PLANETARIUM TO OPEN IN PHILADELPHIA

America's second planetarium, the first in the east, opened in Philadelphia on Wednesday afternoon, Nov. 1, as part of the astronomical section of the Benjamin Franklin Memorial and the Franklin Institute.

This device, a gift to the Franklin Institute by Samuel S. Fels, was made by the Carl Zeiss optical works, in Jena, Germany. It is an elaborate projection device, equipped with 119 lenses, by means of which images of all the naked eye stars and planets are projected upon a sheet metal dome 65 feet in diameter.

For the audience seated below a realistic effect of the night sky is obtained, and the lecturer can change it at will. He may show the skies visible from any part of the earth at any time, and with the motions speeded so that a year goes by in as little as seven seconds. There are 18 in operation in Europe. The first in America opened in 1930 in Chicago, and during the past summer has been a popular feature of the World's Fair.

Monday, Nov. 6, the Fels Planetarium was opened to visitors, a total of 28 demonstrations a week being scheduled. Some of these were especially for schools and colleges, but the public is admitted daily from Monday to Friday, inclusive, at 11 a.m., 3:30 and 8 p.m., on Saturday at 11 a.m., 2:30, 4 and 8 p.m., and on Sunday at 2:30, 4, and 8 p.m.

Opening of other sections of the building is planned for Dec. 5. Among these will be the observatory, containing two telescopes for the use of the public, the section of railroad engineering, containing five full size locomotives, the earliest built in 1837, the newest in 1927, and the sections of physics, chemistry and graphic arts. *Science Service.*

FIELD TRIPS IN BIOLOGICAL COURSES

By William J. Tinkle
Marshall College, Huntington, West Virginia

Any investigation of organisms that deserves to be called science has been based upon observation of actual specimens. Some one had to obtain these plants and animals, making excursions into the field necessary. But often the original investigator or his employees make these trips and the students must be content with preserved specimens or even the bare statement of the author of the textbook.

The earliest recorded advocacy of excursions into the field by classes is in Rousseau's famous book on pedagogy, "Emile."[5,6] This was put into practice by Pestalozzi in the first decade of the Nineteenth Century. The idea was brought to this country by Louis Agassiz,[1,2] a native of Switzerland, who spent the latter half of his life teaching at Harvard College. His motto was "Study nature, not books." In 1872, one year before his death, he established on Penikese Island the first Summer Biological Laboratory for teachers.[4] "Here in a remodeled barn, with the swallows flying in and out, to and from their nests still undisturbed between the rafters, and the blue sea beyond, teeming with the life the students were to study,"[4] the project was started. It has been followed by many others of its kind, and has affected vitally the regular science curricula.

Desirous of learning the present extent of field study, Professor M. P. Loy and the author made an investigation into the high school field work of students now in Marshall College. A questionnaire was submitted to students, including, among others, the following questions: "What was the size of your high school?" "Did you have high school Biology?" "Did you have field trips for the study of plants and animals?" "How many for the year?" "Was your teacher well prepared for the field work? Explain." The student was not asked to give his name nor the name of the instructor.

The tabulated results follow:

Total no. students answering	315
Had high school Biology	260
Had no high school Biology	55
At least one field trip per year	135
No field trips during year	125
Per cent students having field trips	51.9
Range in number of field trips	1–20

Average number	6.1
Teachers well prepared	101
Teachers not well prepared	34

Some of the remarks about the preparation of the teacher for the field work are worth noting; being of much more value than the relative number of teachers approved or disapproved. Typical ones approving the teacher follow: "The instructor was a close observer"; "knew many plants and animals at sight"; "had gone over the ground and had prepared every question to fit the situation"; "knew exactly where to go and what material to take along"; "was well prepared to teach us the process of catching insects"; "could answer questions intelligently"; "was a lover of the outdoors and of plants and animals."

The following are some of the typical unfavorable characterizations: "The teacher took no interest in preparing and knowing the subject"; "did not make full explanation of animals and plants"; "The trips failed because we did not keep together"; "The course was poor because we did not even have laboratory periods."

It will be noted that the reports are very diverse. Practically half of the courses included no field work at all, four had only one, while one had as many as twenty. Only one student stated that they were too far from a good field, and the author considers this a mistake. The student was from a school of five hundred in a county that I have found very good for field work. Large cities are most likely to be poor places, but many students from these cities reported ample field work. The data seem to indicate that the amount done depends upon the inclination of the individual instructor.

While it is neither necessary nor desirable that all of the laboratory work be done in the field, a certain amount is valuable. Biology is the science of living things, not of pickled corpses. The chemist tells us that there are marked changes in protoplasm immediately following death; and a dead animal makes a very inferior impression upon young students. Only special courses in Anatomy should be based exclusively upon preserved material; and these should be preceded by more generalized courses. It is true that many living plants and animals can be kept at the school if one has extensive equipment. But the student does not learn the ecology of the organism so well as he does in the field. Furthermore, in our work of training teachers we prefer field trips because they train

the teacher to be resourceful, instead of repining for the cages, aquaria, and greenhouses which he does not have.

On a field trip it is easy to use those pathways to the mind, the senses. A student recently said to me, "On the test I remembered that the apple and the rose belong to the same family because on a field trip you tasted a rose fruit and I did the same, finding it sweet like an apple. If I had merely read it in a book I should not have remembered it."

The objections to this type of work often are easily overcome. The transportation problem here at Marshall College is met by using a bus owned by the school, each student paying a transportation fee of fifty cents per semester. However we make some trips upon the campus; and while teaching in high school I made trips to parks, vacant lots, and street trees, all of which were near at hand. When a student learns something interesting in a near-by place he develops respect for his own neighborhood. Another advantage in a short trip is that the student is not expected to learn an impossible number of forms, as too often is the case on an extended tour.

Discipline should be no problem at all among college students. Discipline in high school courses is made easier if the trips are frequent, and if the student understands that he is to take notes and write a careful report. This seems quite logical if the trip is taken at the regular laboratory period. The class may be reminded that later a practical test will be given. Field work gives an opportunity to teach self discipline, which should be our aim. Tell the students before starting that when they are not seated with a teacher before them their real character is revealed. Then if they are kept busy making observations the problem is solved. Ganong says the number that can be taken profitably is only ten students;[3] while Twiss says thirty-five.[5] From my experience I agree with the latter.

Unfortunately some teachers seem to forget their pedagogy in the field. A Doctor of Philosophy teaching Plant Taxonomy took his class for their first field trip to the wooded shores of a lake where there were many rare plants. A whole Saturday was spent by the professor telling the names of the multitude of plants. No report nor even notes were required of the students. Very few species were remembered. On his own campus were a number of plants, but no attention was paid to them. A teacher of Geology conducted a class of young ladies up a steep talus slope which he himself said was dangerous. An impression of

terror was made upon the class. We should avoid hardships, and even unsightly places.

Often collecting may be combined with observation. While studying trees, leaves and twigs can be collected if the owner does not object. If water animals are the objects of attention they may be caught in nets and kept in aquaria so that their life habits and morphology may be noted in more detail later.

Finally, the teacher must have enthusiasm. Not the gushing kind which goes up to a tree and says, "O you dear oak, how I love you!" when it is not an oak but an elm. The enthusiasm should come from knowing the importance of the organism in the economy of nature. And do not lecture the class on the impressions they should form. Teach about the specimens and these will instill the correct impression.

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SENSITIVE RELAY FROM OLD GALVANOMETER

By WALTER EVERMAN *and* WILLIAM BLAIR
Cotner College, Lincoln, Nebraska

Being desirous of demonstrating the photoelectric effect in our laboratory it was found that a suitable relay was not available. The following article tells of the experimenters' method of improvising a junked galvanometer to serve as a sensitive relay.

The Luxtron Cell used is made to operate on 10 volts with a maximum safe voltage of 45; 4.6 milliamperes flowing in darkness and 7 in the light. In this instance, 22½ volts were used.

The galvanometer was of the D'Arsonval table type, commonly used for elementary work. It was salvaged from discarded equipment formerly used by academy classes.

The six centimeter pointer was used as the contact arm of the secondary circuit. First attempts consisted of placing a metallic plate for the pointer to strike to make contact, but it was found that at the point of contact the fusion of metals prevented circuit breaking when the cell was darkened.

Mercury solved the problem. A small globule was mounted in such a way that the contact arm (pointer) would just touch the mercury. Adjustments were easily made to provide a "make" or "break" at any degree of light intensity.

The smallest amount of current change necessary to make and break the secondary circuit was four-tenths of a milliampere.

GLASS—ITS CHEMISTRY AND MANUFACTURE

By A. M. Platow
The Amp Research Laboratories
Corona, Long Island, New York

The manufacture of glass is indeed an entrancing story. We all appreciate the comfort of our schools, homes, offices, and buildings flooded with light and air and daily witness the practical value of glass in automobile windows, wind shields, railway coaches, trolleys, display windows, bottles, and mirrors. Regardless of where we may turn we will see glass, and can hardly imagine the hardships endured without it. It truly is the handmaiden of the arts and ministers to every science for without it the world would become a place of gloom and low visibility. Inclement weather would make homes mourn in semi-darkness with sunlight never pouring in except in the fairest atmospheric conditions. Millions would suffer from eye strain, headaches and other ills that come from uncorrected vision. All we now know of the planets and stars in remote space depends on glass for without lens, mirror and prism we would have no telescope or spectroscope wherewith to pry into the secrets of the stellar systems, even wireless telegraphy, telephony and the Roentgen Ray depend essentially on high vacuum tubes of glass.

The camera lens has added considerably to the outlook of humanity for by the aid of this carefully wrought bit of glass man is able to illustrate and record his ideas and make known the appearances of things which otherwise he might never see. The moving picture camera too, plays its part in this tale of wonders for it is the lens's record on the film projected to a screen for the enjoyment of millions.

Glass has even lengthened and preserved human life. Without the aid of the microscope and other glass laboratory equipment medical and chemical science would not be able to accomplish its wonders for the scientist must see as well as know the reactions taking place to shear disease of its terrors and scourges and practically eradicate it.

The manufacture of glass dates from the first period of Egyptian history. Its use was confined to ornament and decoration, something to look at rather than look through. Tiberius (A.D. 14–41) brought glass workers to Rome where the trade continued to flourish. In the middle ages Germany and Bohemia developed their glass industry ahead of other countries because

of their native supply of quartz. Glass was first used for windows in England about the 11th century but little success was attained until about 1557 when French artisans were employed in London. In 1670 Venetian workers were brought over to make the heavier and finer kinds and in 1771 the industry became more firmly established.

Today the glass industry has become so wide spread and of so much importance that it has given rise to lesser industries whose sole business is preparing the raw products to be supplied to glass manufacturers alone. When one considers these raw materials listed as follows he can readily appreciate the competition which arises to seek not only a source of but to produce these chemicals in a state of purity sufficient for use in glass:

Sodium carbonate	Na_2CO_3
Silicon dioxide, sand	SiO_2
Calcium carbonate	$CaCO_3$
Calcium hydroxide	$Ca(OH)_2$
Calcium oxide	CaO
Calcium magnesium carbonate	$CaCO_3 \cdot MgCO_3$
Sodium borate, borax	$Na_2B_4O_7 \cdot 10H_2O$
Sodium chloride, salt	$NaCl$
Potassium carbonate	K_2CO_3
Lead oxide	Pb_3O_4
Aluminum oxide	Al_2O_3
Kaolin	$Al_2O_32SiO_2 \cdot 2H_2O$
Feldspars	$\begin{cases} K_2O \cdot Al_2O_36SiO_2 \\ Na_2O \cdot Al_2O_36SiO_2 \\ CaO \cdot Al_2O_36SiO_2 \end{cases}$
Zinc oxide	ZnO

The amounts of these ingredients are varied according to the type of glass desired. Fining agents such as the following are also added.

Calcium fluoride	CaF_2
Sodium nitrate	$NaNO_3$
Potassium nitrate	KNO_3
Ammonium nitrate	NH_4NO_3
Sodium sulphate	Na_2SO_4
Arsenious oxide	As_4O_6

As in all manufacturing processes the first step is the mixing of the raw materials. These are put into a mechanical mixer from which they are fed into a furnace. The first furnaces used

were of the boiler type using direct fire requiring about five tons of coal to make one ton of glass. Today the recuperative type of furnace conserves heat by utilizing the waste gases as they leave the furnace, natural or producer gas being the fuel employed. During the fusing process tiny bubbles of gas are formed and held in suspension due to the viscosity of the melt and to rid the batch of these, fining agents are added, liberating gases which rise in large bubbles collecting the smaller bubbles and bringing them to the surface. In some glass decolorizing agents are necessary, due to natural impurities, such as ferrous silicate found in the raw materials used. This is done by oxidation or the addition of other complimentary colors such as manganese or a combination of selenium and cobalt oxides. In this manner too, by the addition of metallic salts, coloring is accomplished.

nickel or manganese silicates	—violet
cobalt or copper silicates	—blue
iron or cerium silicates	—yellow
manganese, iron and copper	—grey
high manganese or iron content with cobalt, copper silicates	—black
uranium	—opalescent
gold	—red
phosphate or cryolite	—white
iron and manganese (together)	—amber

The complete chemical reaction for the process may be briefly stated as follows:

$$\begin{array}{rcl} SiO_2 + Na_2CO_3 & \text{Heat} & Na_2SiO_3 + CO_2 \\ CaCO_3 & \rightarrow & CaSiO_3 \\ MgCO_3 & & MgSiO_3 \end{array}$$

However other carbonates are present as well as other oxides and give a more complicated silicate than those mentioned thus there can be no definite fixed equation or formula for glass. It can however be expressed in the molecular proportions of

1.2 parts Na_2O to .8 parts CaO to 6 parts SiO_2

Changing the proportions of raw material used together with the ingredients themselves we can regulate the properties of the final glass produced. Sodium glasses as a rule are harder than potassium if they both contain an equal amount of SiO_2, silicon dioxide. Sodium glass's hardness increases however with an increase of calcium and decreases with a decrease of sodium. So-

dium borate adds hardness and if sodium carbonate or calcium oxide are added to lead glass its hardness too is increased. Glasses rich in alkali are more easily annealed at lower temperatures than are other glasses, while the addition of alumina reduces the annealing temperatures. Some typical glass batches are as follows:

Electric bulbs	*Plate glass*	*Window glass*
SiO_2	SiO_2	SiO_2
Na_2CO_3	Na_2CO_3	Na_2CO_3
$K_2O \cdot Al_2O_36SiO_2$	$NaCl$	Na_2SO_4
$NaCl$	Na_2SO_4	$CaCO_3$
MnO_2	C (Coal)	C
NiO_2	As	

Plate glass is made by pouring the melted glass on a table where it spreads out in an even layer. Glass can be worked because it passes from a liquid to a solid state without crystallization and possesses, when in a hot state, ductility and malleability to a great extent. To give it uniform thickness and a smooth finish it is planed down by a heavy roller. After it is planed it is transferred to the annealing furnace which cools the glass gradually. If it is cooled too suddenly it develops great internal strain so that a change in temperature would make it fall to pieces. This process of gradual cooling probably allows the molecules to arrange themselves so that there is no considerable internal strain when the mass is finally completely cooled. When the glass is cold it is cut into sheets of marketable size and polished.

Hollow ware is shaped in molds of metal, wood, carbon or other material. The glass is gathered on a hollow pipe and after shaping by rolling on a polished plate it is blown into the mold and takes its shape. In cut-glass ware, the design is cut on the solid glass with a soft steel, copper or sandstone wheel. The polishing is done on similar wheels of wood fed with rouge or putty powder.

Bottles are made by blowing in a mold and after reheating the neck is finished with a special tool. This method is being superseded by bottle machines which do the pressing and blowing.

Pyrex glass, that used for chemical laboratory work, is a borosilicate made from sodium borate and silicon dioxide. Its low coefficient of expansion renders it less liable, than ordinary glass, to crack under sudden temperature changes. A comparison of the thermal properties can be drawn from the following data:

Thermal Expansion of Glasses

Glass Sample	*Temp. Interval*	*Coeffi-cient*	*Temp. Interval*	*Coeffi-cient*
Commercial Glass	23–445	.107	510–534	.309
Pyrex	21–471	.036	552–571	.151

In the future many of us will undoubtedly have the walls of our homes paneled with colored glass and by regulated lights behind these we will get the effect of ordinary daylight, brilliant noontime or even moonlight. In fact the use of glass as a material of construction is perhaps not a new idea; in the near future we shall no doubt live in glass houses that will transmit Ultra-Violet rays and we may even use glass that is completely flexible.

CHILDREN HEAR TALKS BY PROMINENT SCIENTISTS

About fifteen hundred children met Saturday, November 4th, to hear talks by prominent scientists, in three meetings arranged by The American Institute for its Junior Science Clubs. These meetings were planned with the idea of opening up new fields of work to the young people who are especially interested in science.

Mr. Alfred Knight, Vice President of The American Institute, Fellow of the Royal Astronomical Society, acted as chairman of the General Science Meeting in the Auditorium of City College, at which the audience was composed of children under fifteen years of age.

Dr. Raymond L. Ditmars, Curator of Reptiles and Mammals of the New York Zoological Park. Dr. Ditmars illustrated his talk on "Strange Animal Friends" with three reels of motion pictures, taken by himself. One reel on freak mammals included scenes of sloths, armadillos, giant anteaters, the echidna and the duck-billed platypus. Another reel showed the children many varieties of lizards and turtles. The third reel showed scenes of marine life.

Dr. Ditmars then related some experiences of his recent trip to the American tropics in search of the vampire bats. He described to his wide-eyed audience the eighteen carnivorous bats, with bodies the size of large rats, which he brought back with him. And finished off with a description of his bird killing spider with a leg spread of eight inches.

Mr. Merwin M. Peake, Founder of the Junior Air Squadron of Elizabeth, New Jersey, then switched the topic from the earth to the air. In his talk "Junior Aeronautics for Science Clubs," spirits soared as Mr. Peake began, "How many of you would like to learn how to pilot an airplane?"

Three boys from his own "Air Squadron" went through ground tests to demonstrate how sound must be eyes, ears, nerves and sense of balance. He showed motion pictures of the aeronautical activities of his boys at the Lafayette Junior High School in Elizabeth, all of whom are between eleven and fifteen years of age.

The principles of airplane construction and operation were demonstrated by a large working model.

A PROJECTILE EXPERIMENT

BY OSCAR L. STARR
San Diego Army and Navy Academy, Pacific Beach, California

One of the interesting topics in College Physics is the motion of projectiles. In approaching this study the student develops the usual mathematical theory for the motion of a body thrown into the air, in which he demonstrates that the path of any such object is a parabola, neglecting air friction. He may also develop the formula for the range, i.e., $R = V^2 \sin 2\phi/g$, where R is the horizontal range, V the velocity of projection, ϕ the angle of elevation, and g the acceleration of gravity. He will then solve many types of projectile problems, such as finding the time of flight, the maximum height, etc. In the case of actual projectiles, there is some error, due to air friction; but the parabolic property is important, and the student is readily interested in its applications.

While the mathematical proof that the path is a parabola is easy, we felt that a laboratory experiment that would demonstrate the fact would be useful. Consequently we devised the following experiment, which we have successfully used with our College Physics class.

A small stream of water constitutes the "projectiles." The water is led from the faucet to the constant level water tank, which is about 2½ feet above the table. (See diagram.) From there it goes to the nozzle, which is clamped about 6 inches above the table. Then it streams through the air, and discharges into the sink. The surplus water from the tank discharges directly into the sink from the overflow port of the tank. In this manner the water in the nozzle is at a constant pressure, and the resulting stream is stationary. The nozzle is made from a piece of glass tubing about the size of a pencil, and drawn out so that the orifice is about 2½ mm. in diameter. Under these conditions the stream appears like a beautifully bent glass rod, about 1 meter long, and does not break into drops until just before it reaches the sink.

To the eye the "rod" of water appears perfectly parabolic, no matter what the angle of elevation may be. The experiment lends itself readily to a quantitative proof that the curve is a true parabola. Following is the method we used to prove this fact.

With the nozzle set at any angle from about 20° to 70°, we

proceed to derive the equation of this supposed parabola, using one point and the vertex. Then we find the coordinates of one or more other points on the stream, and see if their coordinates satisfy the equation.

1. Determine the height of the vertex, VA. To do this hold a meter stick just behind the stream at the vertex, holding it loosely at the top so that it acts as a plumb line and hangs vertically. Then allow it to touch the table and read the position of the center of the stream. Also mark the position at the foot of the stick A.

2. Determine in the same way the height of the nozzle tip, SB.

3. Measure the distance AB.

4. Now consider the vertex, V, as the origin of a set of coordinates. Then the coordinates of the nozzle are (x_1, y_1) where $x_1 = -AB$, and $y_1 = -(AV - SB)$.

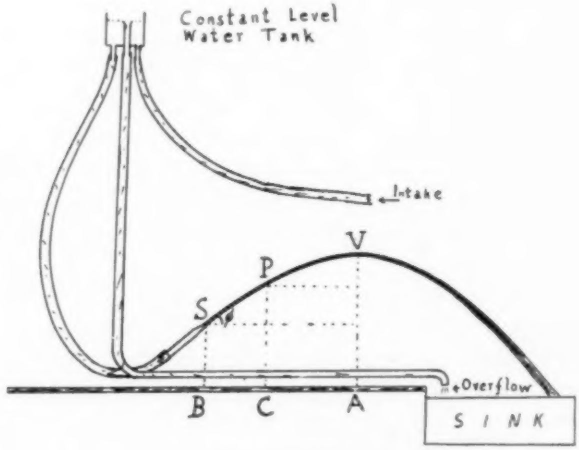

Diagram of Projectile Experiment

5. The equation of any parabola whose axis is vertical and whose vertex is at the origin is $x^2 = 4py$, where p is a constant that determines the shape of the parabola. Now if this stream is a parabola, its equation must be the above one, with some particular value of p. We then determine p by substituting in the equation the values of the coordinates or the nozzle, since this is a point on the supposed parabola. Thus, $x_1^2 = 4py_1$. This equation is then solved for p; calling this value p' the equation of

this parabola is $x^2=4p'y$. This is the equation of the parabola whose axis is vertical, whose vertex is at the point V, and which passes through the nozzle, S. Only one such parabola exists.

6. If the stream is a parabola, it must therefore be the one denoted by the above equation. Then all points on the stream must satisfy the equation. So we next find the coordinates of one or more points on the stream, in the same way that we found the coordinates of the nozzle. Then the coordinates of the point P are (x_2, y_2) where $x_2=-AC$ and $y_2=-(AV-PC)$. These values are then substituted in the equation $x^2=4p'y$. If the two sides of the equation are then equal, the equation is satisfied, and the point P is on the parabola. This may be repeated for as many points as desired.

7. The angle of elevation is changed, a new equation is found, and checked by points on the stream as before.

If desired, the experiment may also be used to prove the range formula, $R=V^2 \sin 2\phi/g$, as follows.

While the stream is flowing, hold a meter stick so that one end rests on the table, while making the stick tangent to the stream at the nozzle by sighting from the upper end. While holding it thus, another student measures the angle ϕ between the meter stick and the table. The angle may be measured with a protractor. The value of g is known, so V is the only other quantity to be determined in order to compute the range from the formula.

To measure V, we first measure the diameter of the nozzle orifice with a micrometer microscope. From this we compute the cross-sectional area of the stream at the nozzle. Then we catch the stream in a large beaker for an exact time and measure it in a graduate. From this we compute the number of cc. per second flow. The velocity V is evidently the volume in cc. discharged per second divided by the area of cross-section.

Having found the velocity V, we substitute the known values of ϕ, g, and V in the equation $R=V^2 \sin 2\phi/g$ and compute R. To check this value of R, we need only to observe that the actual range of the stream is equal to $2AB$, and compare this with the computed value of R.

Of course, there is likely to be a small amount of error due to the errors of measurement. In our experience, however, the error in the results when performed by students seldom exceeds 2 per cent.

A CRUSADE AGAINST THE USE OF NEGATIVE NUMBERS

By G. A. Miller
University of Illinois, Urbana, Illinois

The history of mathematics sometimes exhibits difficulties which the student of modern mathematics is apt to overlook as a result of the modern methods of approach to the various subjects. While the teacher of mathematics should adopt those methods which avoid unnecessary difficulties it is a great advantage to him to understand some of these difficulties so that he may be able to avoid them wisely instead of ignorantly. The teaching of mathematics is somewhat similar to the piloting of a ship into a dangerous port. The most important qualification of the pilot is that he knows a safe route, but if he knows also where the points of danger are he is in a much better position to act wisely in cases of emergencies.

The modern student of mathematics usually becomes acquainted with the use of the negative numbers by such gradual and apparently safe steps that he may be surprised when he learns later that even in the eighteenth century the use of these numbers rested on such an insecure theory that some professors of mathematics in the universities then thought that their use should be discontinued. It appears that the greatest opposition to the use of negative numbers in algebra developed just before the dawn of clear light on this subject near the beginning of the nineteenth century. Among the well known opponents to this use was Robert Simson who was professor of mathematics in the University of Glasgow for fifty years beginning with 1711 and edited a well known edition of Euclid's *Elements*.

One of the serious obstacles in the way towards accepting the negative numbers as real numbers is that this acceptance implies that we cannot thereafter continue to support the view that the ratio of a smaller number to a larger number must differ from the ratio of a larger number to a smaller since it is obvious, for instance that $2/3 = -2/-3$ and that 2 is smaller than 3 while -2 is larger than -3. The example of greatest historical interest in this connection is $1/-1 = -1/1$. In dealing only with positive numbers it is obvious that the ratio of a smaller number to a larger one is always less than unity while the ratio of a larger number to a smaller number is always greater than

unity, and hence two such ratios cannot be equal to each other in this restricted number field.

This difficulty is the more serious in view of the fact that the concepts of ratio and proportion are among the earliest mathematical concepts and that in Greek mathematics the latter largely replaced our modern concept of equation. In all these early uses of the concept of ratio, including the golden period of Greek mathematical developments, the ratio of a smaller number to a larger number was always assumed to be less than the ratio of a larger number to a smaller number. The former corresponds to a proper fraction while the latter corresponds to an improper fraction, but the division of fractions into these two classes was inaugurated after the middle ages although the Hindus calculated already with fractions whose numerators are larger than their denominators. I. Newton and others defined a number as the ratio between two line segments.

These examples of the early use of the concept of ratio are cited here in order to exhibit more clearly an explanation of the reluctance with which mathematicians of the seventeenth and of the eighteenth centuries abandoned the idea that the ratio of a larger number to a smaller number is not always greater than the ratio of a smaller number to a larger one. In 1768 W. J. G. Karsten, who was then professor of logic and later professor of mathematics in a German university, published an article under the title "Von den Logarithmen verneinten Grösen" in which he argued that a negative number cannot be less than zero because if this were true it would follow from the correct proportion $1:-1=-1:1$ that the larger of two numbers may have the same ratio to the smaller as the smaller to the larger, which seemed to him to be a contradiction.

The title of the article just cited suggests the fact that the study of logarithms appeared to some to make it desirable to banish the use of negative numbers from mathematics since the logarithm of -1 was at first supposed to give rise to contradictions. G. W. Leibniz thought that since a positive logarithm corresponds to a number which exceeds unity and a negative logarithm corresponds to a positive number which is less than unity there could be no logarithm of -1, and hence since the ratio of 1 to -1 has no logarithm it is itself imaginary. Cf. *Leibnizens mathematische Schriften*, volume 3 (1855), page 881. Such noted mathematicians as John Bernoulli and J. D'Alembert contended on the contrary that the logarithm of -1 should be re-

garded as 0. The controversy with regard to the logarithms of negative numbers extended through the greater part of the eighteenth century and it was natural to assume that actual numbers must have logarithms. At least this assumption was actually made.

In view of the important rôle played by the concept of ratio during the eighteenth century crusade against the use of negative numbers the following obvious theorem seems to deserve to be formulated at this point. *A necessary and sufficient condition that the ratio of a smaller number to a larger number is equal to that of a larger number to a smaller is that the terms of each one of these two ratios can be obtained by multiplying the corresponding terms of the other by a given negative number.* In particular, when these two ratios are reduced to their lowest integral terms the corresponding terms differ only with respect to sign. This theorem exhibits clearly to what extent the concept of the equality of ratios was affected by the introduction of the negative numbers. The fact that a ratio is not changed by multiplying both of its terms by the same positive number constitutes the basis of the ancient theory of proportion and hence this fact was not questioned at the time of the crusade under consideration.

The eighteenth century crusade against the use of negative numbers was largely influenced by the fact that the nature of the discontinuity of the real number system at infinity was then misunderstood by many mathematicians. L. Euler (1707–1783) pointed out that the negative and the positive numbers are connected both at 0 and also at ∞, but it took a long time for mathematicians to understand clearly that this connection is continuous at 0 and discontinuous at ∞. Near the close of the seventeenth century J. Wallis expressed the view that a negative number is greater than infinity in view of the fact that the reciprocal of a positive number increases as this positive number decreases and it seemed natural to assume that this increase continues when the number passes through zero, as is exhibited by the following inequalities:

$$\cdots 1/4<1/3<1/2<1/1<1/0<1/-1<1/-2<1/-3<1/-4 \cdots$$

It therefore seemed natural to assume that every negative number exceeds infinity. This view was adopted by many of the eighteenth century writers on mathematics notwithstanding the fact that the given inequalities are based partly on

the assumptions that -1 is less than 0 and that $1/0=\infty$.

The fact that the real numbers increase continuously from $-\infty$ to $+\infty$ and then jump in one leap to $-\infty$ is fundamental in the history of negative numbers. In the seventeenth century even such an eminent mathematician as R. Descartes did not realize this fact since he supposed that the negative numbers increased with the increase of their absolute values, according to the *Encyclopedie des Sciences Mathématiques*, tome 1, volume 1, page 35. The development of analytic geometry and the graphic representations of the trigonometric functions during the seventeenth and the eighteenth centuries gradually led to a realization of this fundamental fact but it does not seem to be known yet who first formulated it explicitly. The graph of the tangent of an angle as the angle increases through 180° from $-90°$ to $+90°$ exhibits clearly the nature of the system of real numbers and it is known that R. Cotes (1682–1716) left a manuscript in which the graph of the tangent is given through two periods. This suggests the single point of discontinuity in our system of real numbers.

In addition to the three noted sources of trouble which perturbed many of the mathematicians of the eighteenth century as regards the legitimacy of the use of negative numbers there was a fourth to which attention had been called by H. Cardan (1501–1576) and others, viz., that it had never been proved satisfactorily before the close of the eighteenth century that the product of two negative numbers is a positive number. Even L. Euler failed in his efforts to explain this fundamental fact in his standard work entitled *Vollständige Anleitung Zur Algebra*, 1770, and an earlier noted German writer C. Clavius attributed his inability to explain this fact to the weakness of the human mind. He added however, in his algebra (1608) that the correctness of the rule cannot be doubted since it has been confirmed by many examples.

It should be emphasized that while there was a crusade against the use of negative numbers in the eighteenth century the leading mathematicians continued to use them advantageously and the evidences of their usefulness continued to accumulate. In particular, the trigonometric functions were first regarded explicitly as pure numbers during this century and logarithms began then to be clearly formulated as exponents. Those who longed for the return of the good old Greek times when negative numbers were unknown longed for a mathematical

civilization which had seen its day but could never be recalled. Negative numbers had come to stay and it became imperative for the mathematicians to provide food and shelter for them and to give them admittance to the social standing corresponding to their usefulness.

One of the most prominent names in the eighteenth century crusade against the use of negative numbers is F. Maseres who was a fellow of Clare-Hall, Cambridge, England, and published in 1759 a tract entitled "On the use of negative sign in algrebra" in which he aimed to prove the desirability of excluding the negative and the imaginary numbers from algebra. In particular he stated that the expression $a-b$ has no meaning when $a<b$ and that $(-5\cdot-5)=25$ means merely that $5\cdot 5=25$ without regard to sign, or it is entirely without sense. The fact that the crusade against the use of negative numbers was not then confined to England and Germany results from a note in the *Encyclopedie des Sciences Mathématiques*, tome 3, volume 2, page 3, where it is stated that the real reason which inspired the researches of the noted French mathematician L. N. M. Carnot (1753–1823) was his aversion for negative numbers, which he rejected because he thought that their use led to erroneous conclusions.

While a and $-a$ represent reciprocal operations in the group of addition they are not reciprocal in the group of multiplication but in this group a and $1/a$ are reciprocals. This difference caused considerable trouble to many of the eighteenth century mathematicians who sometimes defined negative numbers by means of their operational property in the group of addition but failed to realize that this property is not the same in the group of multiplication. In fact, in this group the negative number has a two-fold property since it not only extends or contracts the modulus of the multiplicand but also turns it as a vector through 180°. The comparison of negative numbers with debts when the corresponding positive numbers represent credits, or with distances in the opposite direction from those represented by the corresponding positive numbers relates to the operational property of these numbers as regards the group of addition but not as regards the group of multiplication. The eighteenth century crusade against the use of negative numbers was largely due to a misunderstanding of the widely different rôle relative to positive numbers which the former play in the groups of addition and the group of multiplication respectively.

In piloting the mathematical ship into the port of negative numbers the teacher should bear in mind that he is piloting it around points where many have encountered serious troubles. These troubles are not only matters of history but they may also become sources of enlightenment since such a remarkable tool as the negative numbers now constitute cannot be too carefully studied. It is especially interesting to note that after it had been used more or less for centuries there were still those who were opposed to this use. Their frank and open opposition seems to have been the most effective step towards removing points of weakness and towards hastening the day when there was no longer any reason for opposition. This victory seems to be permanent.

WHAT IS A SCIENTIFIC ATTITUDE?

By George J. Skewes
University High School, Madison, Wisconsin

I should like to believe that high school courses in natural science develop in the pupils who take such courses a truly scientific attitude. Yet this desire is the arch enemy of a scientific attitude. When I am anxious to believe that my teaching has been helpful in developing a scientific attitude in my pupils I am apt to be unscientific in judging results. Nor am I the only science teacher in this dilemma. For years science teachers have claimed that pupils should study natural science in order to develop a scientific attitude, yet there is no evidence that enrollment in science classes improves one's scientific attitude. What is this will of the wisp we are following? What is a scientific attitude?

When the Wisconsin State Science Committee attempted to formulate a statement of the philosophy of science teaching the question of scientific attitude arose. After a great deal of study and discussion this committee decided to list specific objectives of science teaching without classifying them under attitudes, methods, information, skills, and appreciations. These specific objectives are included in "A Wisconsin Philosophy of Science Teaching" (School Science and Mathematics, October 1932).

But after the publication of this philosophy the question of scientific attitude still persisted and the committee undertook as one of its activities during the past year to clarify a definition

and to take steps toward devising means for determining the presence or absence of a scientific attitude.

It must be remembered that a definition of scientific attitude cannot be secured from a dictionary, nor can a satisfactory definition be secured from other sources. Many individuals have attempted definitions but none of these are generally enough accepted to be used. The great variety of definitions offered suggests the possibility that a scientific attitude differs with the situation; that there are really a number of component elements using the generic name and that some of these may be called forth at one time and some at another. The committee became convinced that identification of these component elements was necessary.

The task of identifying the various elements included in a scientific attitude was undertaken by the chairman of the committee, Mr. Ira Davis of the University High School at Madison. He sent out the following questionnaire to 150 experienced science teachers in Wisconsin and to 100 outside of the state who were members of the National Association for Research in Science Teaching, The National Council of Supervisors of Elementary Science, or The Central Association of Science and Mathematics Teachers. These teachers of high standing in the profession should be able to judge whether any given characteristic is an integral part of a scientific attitude. It is suggested that before you examine the tabulation of returns made by these leading science teachers that you take a pencil and check the suggested list indicating your judgment as to whether each characteristic is included in a scientific attitude.

CHARACTERISTICS EXHIBITED BY PERSONS HAVING A SCIENTIFIC ATTITUDE

If you think the following characteristics should be exhibited by persons having a scientific attitude, write *YES* in the blank space provided for each statement; if not, write *NO*. There is some over-lapping in the statements as made. Space is provided for explanations of your answers if you care to make them.

1. ________ Power to distinguish between fact and theory.
2. ________ Concept of cause and effect relationships.
3. ________ Free from superstitious beliefs.
4. ________ Habit of basing judgment on fact.
5. ________ Respect others opinions.
6. ________ Willingness to change opinions on basis of new evidence.
7. ________ Ability to make observations.

8. ________ Tendency not to overstate the facts in any situation.
9. ________ Skeptical of all unproven knowledge.
10. ________ Appreciate the degree of control man has over his environment.
11. ________ Search for the whole truth regardless of personal, religious, or social prejudice.
12. ________ Suspend judgment on any question until all necessary facts are known.
13. ________ Desire to do something to hasten human progress and to add to the store of human knowledge.
14. ________ Habitual use of the scientific method in solving problems met in every day life.
15. ________ Skeptical about all "unexplained mysteries."
16. ________ Tendency to be neat, clean, accurate, and punctual in all forms of endeavor.

Teachers were also asked to suggest additional characteristics and to formulate a definition of a scientific attitude.

In making up this list, characteristics suggested by various writers were included as well as some characteristics which might be exhibited by scientists but which were not, in the opinion of the committee members, included in a scientific attitude. Inclusion of those extraneous characteristics served to identify the replies of those who gave little thought to differentiating characteristics but who yielded to the suggestion of the printed page.

A total of 162 replies was received to the questionnaire. Seventy of these accepted all of the sixteen suggested characteristics as typical of a scientific attitude. For purposes of tabulation these replies were eliminated because they did not aid in discriminating among the characteristics. The following tabulation of the 92 replies used rearranges the characteristics in order of the number accepting each and gives the number accepting and rejecting each as well as those who expressed themselves as doubtful.

Rank	*Characteristic*	*Yes*	*No*	*Doubtful*
1.	Willingness to change opinion on basis of new evidence	92	0	0
2.	Search for the whole truth regardless of personal, religious or social prejudice	89	2	1
3.	Concept of cause and effect relationship	86	3	3
4.	Habit of basing judgment on fact	85	4	3
5.	Power to distinguish between fact and theory	82	6	4
6.	Free from superstitious beliefs	81	4	7

7. Tendency not to overstate the facts in any situation	79	10	3
8. Suspend judgment on any question until all necessary facts are known	78	5	9
9. Ability to make observations	77	13	2
10. Habitual use of the scientific method in solving problems met in everyday life	73	15	4
11. Respect others opinions	66	10	16
12. Skeptical about all "unexplained mysteries"	64	15	13
13. Skeptical of all unproven knowledge	59	22	11
14. Appreciate the degree of control man has over his environment	54	25	13
15. Desire to do something to hasten human progress and to add to the store of human knowledge	41	33	18
16. Tendency to be neat, clean, accurate and punctual in all forms of endeavor	35	40	17

It is probable that agreement by seventy-five per cent of competent judges is a valid criterion, but to be on the safe side it was decided to require acceptance of a given characteristic by ninety per cent of the judges. The first five characteristics on the rearranged list include all which meet this requirement. Thus it can be said that an individual who has a scientific attitude (1) will show a willingness to change his opinion on the basis of new evidence; (2) will search for the whole truth regardless of personal, religious, or social prejudice; (3) will have a concept of cause and effect relationships; (4) will make a habit of basing judgment on fact; and (5) will have the power to distinguish between fact and theory. He may also possess other characteristics but he must possess these if ninety per cent of the judges agree that he has a scientific attitude.

The task then arises to devise valid tests for determining the presence in an individual of each of these characteristics. For years science teachers have used tests of information, but different tests are needed for testing attitudes. There is also the danger that when tests of attitude are given that the pupil will respond as he believes the teacher wants him to respond rather than in a manner consistent with his own inclinations. The State Science Committee faces the problem of constructing tests which will be real indices of the pupils' attitudes.

Examination of the five characteristics reveals that three of them center around the idea of coming to a proper conclusion from evidence rather than holding a prejudiced opinion. This is variously expressed as "Willingness to change opinion on the

basis of new evidence," "Search for the whole truth regardless of personal, religious, or social prejudice," "Habit of basing judgment on fact." Some indication of the possession of these characteristics can be secured if a pupil's attitude in regard to some controversial matter can be secured and then his reaction obtained to specific situations in which the evidence supports the opposite conclusion from the general rule of procedure he originally espoused. Construction of such a test is now being attempted.

An entirely different test is being constructed to test the concept of cause and effect relationships. Not only is it essential to know whether or not a pupil realizes that for any effect there must have been a cause, but it must also be ascertained whether the pupil recognizes the adequacy of a supposed cause to produce the given result. The success of this test will be reported at a later date.

A third test is being attempted to test the capacity to distinguish between fact and theory. The difficulty in this is to eliminate the effects of past teaching. When textbook writers have indoctrinated theories as facts the diligent student may suffer if the problems presented are taken from such material.

These three suggested tests are not called tests of a scientific attitude, but rather tests of elements inherent in a scientific attitude. In a similar way tests may be devised to test other specific characteristics. Measurement of a scientific attitude can only be achieved by careful determination of specific elements. While the totality of attitude is determined by combining these elements no assumption can be made that they are positively correlated, and no arithmetical addition of scores on various tests can be used to give a single index of scientific attitude.

When tests of the various elements in a scientific attitude have been devised a great field of experimentation in connection with science teaching will be opened. First, science teachers must determine objectively whether science courses do promote a scientific attitude in pupils taking such courses. The respective merits of various courses should also be determined. Perhaps non-science subjects are equally effective in developing a scientific attitude, but more fundamental experimentation must be carried on to evaluate various teaching procedures to the end that science teaching may be improved and the objectives of science teaching realized to a fuller degree.

A LIGHT INTENSITY METER FOR FIELD USE

By Lester H. Cushman
University of Southern California, Los Angeles, California

INTRODUCTION

The light intensity meter described is a light-weight, portable instrument for field use; its applicability to various sorts of investigations is evident. It can be assembled for so small a cost[1] that it is one of the least expensive of the newer photoelectric meters serving the varied purposes of this one. Readings can be made in light intensities of from 6–8 to about 10,000 foot candles, or practically full sunlight. Both the entire visible spectrum[2] may be measured, or, on the other hand, by employing

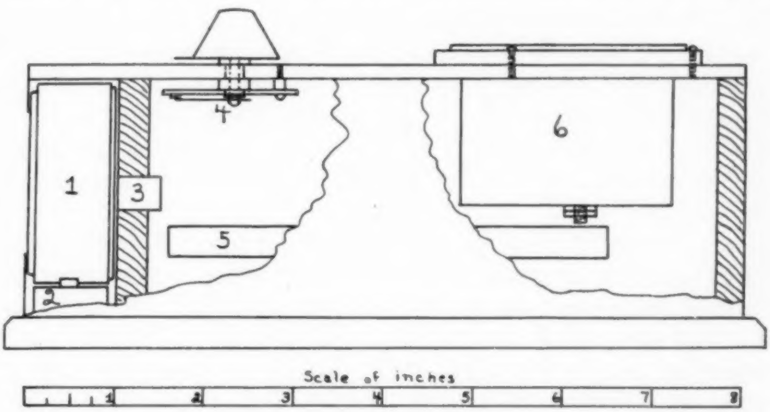

Fig. 1. Cut-out side view, showing internal construction.
1. Weston Photronic Cell.
2. UX tube socket.
3. Plug for extension cord.
4. Four-point switch.
5. Electrad adjustable resistors (wire-wound).
6. Weston 0–50 microammeter.

certain color filters, portions only of the spectrum may be measured. The assembled instrument is strong, simple in operation, and does not easily get out of order. Five different meters have been built and the one described embodies the results of the experience thus gained. The work was done under the direction

[1] Less than thirty dollars, California 1932–33.

[2] The instrument actually has a somewhat wider range; the expression "visible spectrum" is used for convenience.

of Dr. H. de Forest, Department of Botany, University of Southern California, Los Angeles. Mr. Loren T. Clark, Assistant Professor of Physics at the same institution, has very kindly examined the paper critically and several of his suggestions have been made use of in the work.

CONSTRUCTION

Figure 1 supplies construction plans. The necessary parts comprise a dry plate type of photoelectric cell, a microammeter, shunt resistances, and a switching device by means of which different resistors can be connected in shunt with the microammeter. These are installed in a wooden box measuring $3 \times 4\frac{3}{4} \times 8$ inches. The photoelectric cell employed is a Weston Photronic Cell.[3] This requires no vacuum, gas, or liquid. It should not be subjected to external voltage, since then the cell may be burned out; it can, however, be exposed to intense light, even full sunlight, without causing deterioration. The cell is set in the instrument with its face flush with the outside of one end of the cabinet. On the outside of the cover the meter and switch are inset, and between these, but on the inside of the box, are supported the resistors.

The electrical connections are shown in figure 2. Both resistors should be of adjustable type and supplied with extra clips so that the several shunt resistances may be correctly set. The electrad adjustable resistors are a special type of rheostat with standard wire in the coils. The clips are adjusted by sliding them along the resistor, so that each higher numbered point on the switch multiplies the reading on the instrument by ten, thus requiring a light intensity ten times as great to give the same reading on the microammeter. Hence a light intensity that would give a reading of 50 microamperes with the switch set on tap 1 would give a reading of only 5 microamperes with the switch set on tap 2. The cell delivers about 1 microampere per foot-candle light intensity averaged over the entire surface of the cell face, or about 120 microamperes per lumen.

Holders are attached to the cell for maintaining before its face various color filters,[4] for use when it is desired to measure the intensity of a portion only of the visible spectrum. Provision is made also for plugging in an extension cord several feet in

[3] The Weston Photronic Cell #594. Weston Electrical Equipment Co., Newark, N. J. "Photronic" is a trade term.

[4] Wallace Color Filter Set. Central Scientific Co., Chicago, Ill.

length, thus permitting the cell to be used at a distance from the cabinet in places where the entire apparatus could not conveniently be placed. The maximum weight of the complete set-up need not exceed two pounds.

CALIBRATION FOR THE ENTIRE VISIBLE SPECTRUM

The instrument must be calibrated for the individual "photronic" cell installed in it, and the accuracy of the light meter will depend upon the care with which this calibration is carried out. In any case the accuracy of the method can be no better than the accuracy of the particular Weston cell.

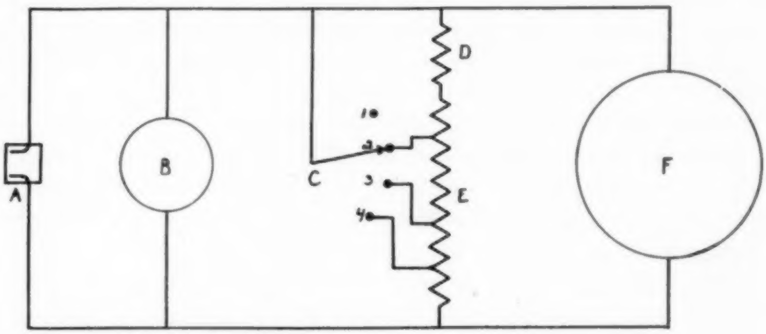

FIG. 2. The electrical circuit.
A. Plug for extension cord.
B. Weston Photronic Cell.
C. Four-point switch.
D. Electrad adjustable resistor (wire-wound), 75 watt, 5000 ohms.
E. Electrad adjustable resistor (wire-wound), 75 watt, 200 ohms.
F. Weston 0–50 microammeter.
1. Not connected with resistor.
2, 3, and 4. Switch points connected to clips on the adjustable resistor E.

The apparatus used in this calibration consists of a Weston foot-candle meter, a 500 watt stereopticon light, and some blackened (exposed) photographic plates.

First the resistors are adjusted, as follows. The light meter is placed on a line normal to the plane of the filament of the light, and with the face of the photoelectric cell normal to the same line, at such a distance that the intensity of the illumination is 50 foot-candles as measured by the foot-candle meter. The distance from the lamp to the meter must be at least ten

times the diameter of the filament, or no closer probably than two feet. The switch is set on tap 1 and the adjustable clip on the 5000 ohms resistor is moved until the meter reading is just 50 microamperes, then the clip is tightened to prevent its movement. Now, without moving the light meter, the switch is turned to tap 2 and the clip electrically connected with that tap is slid along the 200 ohms resistor until the microammeter reading is 5. The light meter is now moved nearer to the light until the meter reading is again 50 microamperes. Then the switch is turned to tap 3 and the associated clip is adjusted until the meter again reads 5 microamperes. With the switch set on tap 4 the reading should be 5 microamperes in a light intensity that will give a reading of 50 microamperes on tap 3.

Having completed the adjustment of the resistors it is advisable to apply to them a coat of lacquer or shellac, in order to prevent alteration in the resistance values.

For light intensities within the range of the foot-candle meter the calibration data for the light meter may be found by direct comparison, that is by placing the foot-candle meter and the light meter at different distances from the light source and recording the readings of both instruments at each distance employed. Calibration graphs should now be constructed for as far as the data obtained will permit.

Calibration data for greater intensities than the above may be found as follows. Choose a piece of darkened (exposed) photographic plate that will allow about one-tenth of the light to pass through. Place the light meter sufficiently close to the light to give a reading near the upper limit of the calibrated range of the light meter. The graphs as already constructed furnish this calibration, of course. Record the reading, then place the darkened plate directly in front of the photoelectric cell and record the new reading thus obtained. The foot-candle intensity, as interpreted from the graph, without the plate in place, divided by the foot-candle intensity with the plate in place gives a constant that may be used to calculate the higher intensities. To find the reading for an intensity of about 500 foot-candles, the light meter with the darkened plate in place is moved close enough to the light to afford an intensity of illumination (as interpreted from the first graph) of 50 foot-candles. The intensity of the light at that distance is then 50 times the constant determined, or about 500 foot-candles. The darkened plate is then removed and the intensity of illumination and the reading of the

light meter recorded. Other calibration data for tap 2 are obtained in like manner. When this graph is completed, data for the higher intensities may be obtained similarly; both the first and second ranges (taps 1 and 2) of the light meter, of course, may be now employed in the calibration of the two higher ranges. Range three may be used in the calibration of range four. At the time of calibration it is advisable to establish a secondary standard against which the photoelectric cell may be checked from time to time. This is accomplished by first testing the photoelectric cell. A rheostat is connected in series with a 100 watt bulb and the lighting circuit of the building. The rheostat is then adjusted until the reading of a voltmeter connected in parallel with the lamp is nearly the same as the rated voltage of the bulb. Storage batteries may, of course, be employed instead

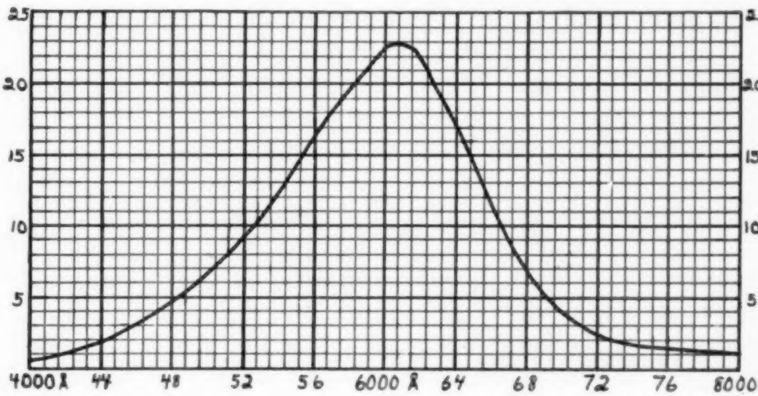

FIG. 3. Relative response curve of a Weston Photronic Cell #594 with a plain glass window.

of this set-up. With the switch of the light meter set on tap 1 the instrument is placed sufficiently close to the light to give a reading which is about one-half the maximum scale reading, that is about 25 microamperes. The readings of the microammeter, and of the voltmeter, with the distance from the center of the light to the face of the photoelectric cell, are recorded for future checking of the cell. The side of the bulb facing the light meter must also be marked, so that this same side may be so presented again. Readings taken later with the same set-up should not vary from the original reading by more than one per cent.

The accuracy of the light meter is now checked. The ac-

curacy of the instrument when the switch is set on tap 2 is found by now moving the instrument close enough to the lamp to give a reading of 50 microamperes when the switch is set on tap 1. The switch is now turned to tap 2 and the reading observed. These readings, when translated into foot-candles by the use of the calibration graphs, should afford results that vary by less than five per cent. Tap 3 may then be checked against tap 2, and tap 4 against tap 3, in like manner.

CALIBRATIONS FOR PORTIONS OF THE VISIBLE SPECTRUM

When used with a color filter before the face of the cell the instrument measures the intensity of the light passed by the filter. The cut-off for each filter of the Wallace Color Filter set was determined with a spectrometer, and only such of them as showed sharply defined limits of transmission were selected, these being numbers 2, 7, 8 and 9. Filter number 2 may be employed for the red end of the spectrum, about 6000–8000 Ångstrom units; number 7 for the green region, about 4950–5850; number 8 also for the green, about 4300–5600; number 9 for the violet portion, about 3500–5200. Other filters, or combinations of filters, can be used which will permit the measurement of intensities of narrower bands of the spectrum.

Calibration for color filters is accomplished as follows. The response curve, figure 3, was determined by means of a monochromator and a white light source. In the set-up the eyepiece of the monochromator was replaced by the photoelectric cell. Then the readings of a galvanometer, connected in series with the cell, were plotted on coordinate paper as a function of the wave-length of the incident light. This response curve will, in all probability, vary slightly with different individual cells; for the same cell, however, the curve should remain constant throughout the life of the cell it represents.

After establishing the response curve there is then to be found the fraction of the light from a white light source, such as a tungsten filament bulb, which is transmitted by each filter for the band of wavelengths which it will pass. This is done by placing two filters of the same color between the white light source and the light intensity meter, that is to say in the instrument over the face of the photoelectric cell. The meter is then read. One of the filters is now removed, and the meter is read again. The larger reading (when one filter is in place) divided by the smaller reading (when both filters are in place) gives a

quotient which may be termed the transmission factor for the filter removed.

There must now be found the average height of the response curve, figure 3, for the portion of the light passed by the filter used, as explained below. These two steps are repeated for each particular filter to be employed.

The following will serve to make this procedure clear. To correct a field reading taken with a color filter in place in the instrument, multiply the meter reading by the transmission factor, and also by the average height of the response curve, and then divide by the average height of the response curve for the band of wavelengths passed by this color filter. The average height of the response curve is found by dividing the area of the curve (obtained by counting the coordinate paper squares contained in it) by the length of the horizontal axis, the abscissa, that is included by the curve. As an example, suppose a green filter is placed in the instrument, and that this filter passes light of wavelengths 5000–5500 Å.U., and that it has a transmission factor of 1.5. Suppose the reading of the microammeter is 10 when the switch is set on tap 2. This, by the calibrating graph for tap 2, is equivalent to 100 foot-candles. The average height of the response curve is found to be 25 units. The average height of the curve for the wavelengths passed by the filter is 22 units. The corrected reading, then, is: $100 \times 25 \times 1.5/22 = 170$. This means that the intensity of the green light in the locality is 170 foot-candles. In case filters are used which do not have sharp cut-offs it would be necessary to find a response curve for each particular filter.

OPERATION OF THE INSTRUMENT

When the maximum light intensity in any location is desired the orientation of the photoelectric cell must be altered until the highest reading of the meter in that location is obtained. In other words, the plane of the photoelectric cell face must be made perpendicular to the path of the incident light, so that the highest current is obtained. When the light meter is to be operated so as to be affected by some definite light source a visor or shield can be applied to the instrument to shut off other light than the desired source.

After pointing the instrument properly the reading of the microammeter is taken and the setting of the selector switch noted. This switch may be set on points 1, 2, 3, or 4. Point 1 is

for very low light intensities, point 4 for the highest intensities or direct sunlight, the remaining points for intermediate ranges. Reference is then made to the calibration graphs made for the instrument, one graph for each of the four switch points. Using the graph for the switch point that was employed in taking the reading the foot-candle power is read on the horizontal coordinate for the observed meter reading as indicated on the vertical coordinate of the graph.

It is best to keep the switch set on point 4, turning it to the other more sensitive points only as necessary in using the meter. By this the pointer of the microammeter will be kept from being unnecessarily forced beyond the highest reading of the scale.

The metal contact points for the four taps should be cleaned occasionally with strong alcohol applied with a camel's hair brush.

SUMMARY

The photoelectric cell mentioned has been found to be conveniently adaptable for a portable light intensity meter for field use, one of wide range, from about 6–8 candle power to about 10,000, or full sunlight. The necessary accessories are a microammeter, a switching arrangement, adjustable resistors, and an extension set. When assembled in a small cabinet the weight is but two pounds at the maximum. The meter is calibrated by means of a foot-candle meter and a light source. Different shunt resistances act as multipliers to give the higher readings. By means of a response curve the readings of the meter may be corrected when color filters are used, correction being made for the light absorbed by the filter. The accuracy of the instrument depends upon the care taken in its calibration, within, of course, the limits of the photoelectric cell itself. It supplies excellent approximations of light intensity values. The assembled instrument is susceptible of ordinarily rough field usage and its cost is relatively low.

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MORE MATHEMATICAL FALLACIES

By Cecil B. Read

Assistant Professor of Mathematics, The University of Wichita, Wichita, Kansas

Following the appearance of an article on Mathematical Fallacies in the June issue of School Science and Mathematics the writer was surprised to receive more than a score of inquiries. Several requested information regarding some of the fallacies mentioned, but the major portion requested more examples. The most interesting inquiry regarding fallacious proofs was that of a student about to enter college, who asks, "If mathematics proves things common sense tells us are false, why study mathematics?" He is more or less in the position of the old colored mammy who protested the size of her grocer's bill. "Why, mammy," retorted the grocer, "there are the figures, and you know that figures don't lie." "No," replied mammy, "but I does know that liars do figure." Perhaps it is the purpose of discovering where the liars are busy that makes us interested in the queer results arising from fallacies.

Acting on suggestions offered by a few of those interested in the matter, it is the purpose of this article to merely present a few fallacies, with no attempt to explain or locate the flaw. It is almost impossible to give the source of most of these problems. The writer has found the same fallacy in various forms in several different places, and would hesitate to defend any claim of priority. A brief bibliography is given at the end of the article; personally I have found Ball's book the most fruitful.

Let us first consider a few more of the fallacies classed as absurd in the previous article. To prove that I have eleven fingers: Allow me to count backward from the usual number, ten; starting with the left hand I have ten, nine, eight, seven, six, which with five on the right hand makes eleven.

How many times can 20 be taken from 100? Wrong. Not five times, for give me time enough, and I can repeat as often as you please, the result is 80 in each case.

How many days does the average laborer work in a year? Twenty-one. The proof is easy. Even in a leap year of 366 days, he works only eight hours a day, or 122 days. But there is no work on Sundays, subtract 52 days, leaving 70. Then there are nine legal holidays and two weeks vacation, leaving 47 days.

Then we have a half day off Saturday afternoon, or 26 days off, leaving the 21 days.

Coming to more serious matters, I should like to call attention to one fallacy, quite frequently seen in the work of students, which needs to be guarded against. Required to solve and check the equation

$$1+\sqrt{x+2}=1-\sqrt{12-x}$$

Solution:

$$\begin{aligned} \sqrt{x+2} &= -\sqrt{12-x} \\ x+2 &= 12-x \\ x &= 5. \end{aligned}$$

Check:

$$\begin{aligned} 1+\sqrt{5+2} &= 1-\sqrt{12-5} \\ \sqrt{5+2} &= -\sqrt{12-5} \\ 5+2 &= 12-5 \\ 7 &= 7 \text{ hence answer checks.} \end{aligned}$$

Pupils in geometry are often carefully taught the axioms, some algebra books also emphasize them, but rarely is it pointed out that we may follow the axioms, yet come out wrong. Given the equation

$x-2=4$		
$x^2-3x+2=4x-4$	Multiply by $x-1$.	Equals multiplied by equals, etc.
$x^2-4x-12=3x-18$	Subtract $x+14$.	Equals subtracted, etc.
$x+2=3$	Divide by $x-6$.	Equals divided by equals, etc.
$x=1$	Subtract 2	Equals subtracted from equals, etc.

At every step we followed an axiom, yet the result is obviously wrong. Let us now violate an axiom and watch the results. Starting with the same equation as before, we shall add five to the *left member only.*

$x+3=4$	
$x^2-3x-18=4x-24$	after multiplying both sides by $x-6$
$x^2-x=6x-6$	obtained by adding $2x+18$ to each member
$x=6$	dividing both sides by $x-1$.

In this case we have a *correct* result, obtained after a serious *violation* of an important axiom.

From geometry, we have the theorem in proportion: In any proportion, if the first term is greater than the second, then the third is greater than the fourth. Application of this theorem to algebra yields interesting results. Given the proportion $1:-1=-1:1$. Now apply the theorem, and since 1 is greater than -1, we have -1 greater than 1.

Let us arrive at the previous result in a slightly different manner. Consider the fraction $1/x$. It seems apparent that decreasing the value of x increases the value of the fraction. This is illustrated by letting x run through the sequence 5, 4, 3, 2, 1; then $1/x$ becomes 1/5, 1/4, 1/3, 1/2, etc. Now we may note that each term of the sequence for $1/x$ is greater than the preceding, i.e. 1/4 larger than 1/5; 1/3 larger than 1/4, etc. Let us continue the process until x takes on the values 1, -1; we then conclude that by the $1/x$ sequence -1 is greater than 1. Since we have now arrived at the result by two methods, we cannot be wrong.

Several have inquired how we may show that log 2 is equal to log 1. There are several methods, of which I shall give two. $\log 2=1-1/2+1/3-1/4+1/5-1/6+1/7-1/8+\cdots$ as can be verified from any calculus text. Let us arrange the positive terms of the series first, then the negative terms.

$$\log 2=1+1/3+1/5+\cdots-(1/2+1/4+1/6+\cdots).$$

Now subtract and add the series in the parenthesis

$$\log 2=1+1/3+1/5+\cdots-(1/2+1/4+1/6+\cdots)$$
$$-(1/2+1/4+1/6+\cdots)+(1/2+1/4+1/6+\cdots)$$

and collect terms, placing the last set of positive terms in order with the first set

$$\log 2=1+1/2+1/3+1/4+1/5+1/6+1/7+\cdots$$
$$-2(1/2+1/4+1/6+1/8+1/10+\cdots).$$

If we simplify the parenthesis, we have $\log 2=0$; but we know $\log 1=0$ hence $2=1$.

A slightly different method of attack starts with the same series for log 2. Multiply the equation by 2, and we obtain

$$2\log 2=2-1+2/3-1/2+2/5-1/3+2/7-1/4+\cdots.$$

Combine terms with common denominators and rearrange

$$2\log 2=1-1/2+1/3-1/4+1/5-1/6+\cdots.$$

But the left member is the series for log 2, hence we have $2\log 2=\log 2$ from which again we obtain $2=1$.

Having proved that $2=1$, let us now prove that it is equal to

zero. For this purpose, let us choose x such that $e^x = -1$; then if we square both sides, we have $e^{2x}=1$. But we know that $e^0=1$, so we have $2x=0$, and therefore $x=0$. Returning to our original assumption, we have $e^x=e^0=1=-1$ hence $2=0$.

An old geometry teacher was accustomed to say, "If in doubt, see if you can arrive at your results in another way." Perhaps we can use some other method to prove that $2=0$. Consider the identity

$$\sqrt{x-y}=i\sqrt{y-x}. \tag{1}$$

Since this is an identity, it is true for all values of (x, y), say (m, n)

$$\sqrt{m-n}=i\sqrt{n-m}. \tag{2}$$

Also, being an identity, it must be true for the values (n, m)

$$\sqrt{n-m}=i\sqrt{m-n}. \tag{3}$$

Let us now multiply equations (2) by (3)

$$\sqrt{m-n}\sqrt{n-m}=i^2\sqrt{n-m}\sqrt{m-n}.$$

Divide out the common factor, and using the fact that $i^2=-1$, we have the result that $1=-1$, hence again we have $2=0$.

To vary the examples, let us consider a problem in probability. If three coins are tossed, what is the probability that all three fall alike? In any toss, two must be alike, that is, two heads, or two tails. The probability that the third coin will fall heads or tails is 1/2 in either case. Hence in one half of the throws, the required condition is satisfied, the answer being 1/2. Or, should we reason: The probability that any one is heads is 1/2, and that all three are heads is $(1/2)^3$, or 1/8? Likewise for three tails, and since either will satisfy the condition, the probability is $1/8+1/8$ or 1/4.

Knowing that Commander Byrd reached the pole, but with no further information, what is the probability that it was Sunday when he got there? Before you answer 1/7, consider just what we mean by Sunday at the pole. What of two planes which approach on opposite sides of the international date line? What day is it when they reach the pole? Is the probability 0, 1/7, 2/7, or 1, or what?

Consider the formula for the area of an ellipse, πab. If we consider only the portion bounded by the curve and the minor

axis, we have $\pi ab/2$. Now let the curve change, the center moving out along the major axis. In any position, the formula holds. But as the center is infinitely removed, the ellipse becomes a parabola. The area of a parabola is two-thirds of the circumscribing rectangle. Hence we have $\pi ab/2 = 2/3\ a\ (2b)$ from which $\pi = 8/3$.

Having just shown that $\pi = 8/3$, we shall now show that it is equal to unity, by proving that the circumference of a circle is equal to its diameter. Let us bisect the diameter and on each radius as diameter construct a circle. The sum of the circumferences of these two circles is equal to the circumference of the original circle, since for each of the small circles it is $\pi d/2$. Now bisect each of the two radii of the large circle and describe circles on each segment as diameter. As before, the sum of the four circumferences is equal to the circumference of the original circle. Now bisect each of the four segments, and on each segment describe a circle; giving eight circumferences, with their sum equal to the original one. Continue the process, at each step, the sum of the small circumferences is equal to the original one. But in the limit, the small circumferences will become the points of the diameter itself, and we shall have the diameter equal to the circumference.

One or two geometrical proofs will be mentioned. No figures will be given, but it is suggested that a figure be drawn. In many cases of geometrical fallacies, the careful construction of a figure will locate the flaw, although it is not asserted that such is the case in any or all of the following.

To prove that a part of a line is equal to a different part. (Often stated: To prove that a part of a line is equal to the whole line.) Let RST be an acute angled triangle in which angle R is larger than angle T. Construct $\angle SRN = \angle T$, with N on ST. Drop RK perpendicular to ST, K being on ST. Triangles RST and RSN, being equiangular, are similar, hence

$$\frac{\text{Area } RST}{\text{Area } RSN} = \frac{\overline{RT}^2}{\overline{RN}^2} = \frac{\overline{RS}^2 + \overline{ST}^2 - 2\overline{ST}\ \overline{SK}}{\overline{RS}^2 + \overline{SN}^2 - 2\overline{SN}\ \overline{SK}}. \tag{1}$$

Also these two triangles are of equal altitude RK

$$\frac{\text{Area } RST}{\text{Area } RSN} = \frac{\overline{ST}}{\overline{SN}}. \tag{2}$$

Now, by combining the equal ratios in (1) and (2)

$$\frac{\overline{RS}^2+\overline{ST}^2-2\overline{ST}\ \overline{SK}}{\overline{ST}}=\frac{\overline{RS}^2+\overline{SN}^2-2\overline{SN}\ \overline{SK}}{\overline{SN}}$$

$$\overline{RS}^2/\overline{ST}+\overline{ST}-2\overline{SK}=\overline{RS}^2/\overline{SN}+\overline{SN}-2\overline{SK}$$

$$\overline{RS}^2/\overline{ST}-\overline{SN}=\overline{RS}^2/\overline{SN}-\overline{ST}$$

$$\frac{\overline{RS}^2-\overline{SN}\ \overline{ST}}{\overline{ST}}=\frac{\overline{RS}^2-\overline{SN}\ \overline{ST}}{\overline{SN}}.$$

Since the numerators are identical, the denominators must be equal, or $ST=SN$.

The next fallacy has appeared in various forms. It is one of the few in which trigonometry is introduced. It is proposed to proved that every triangle is isosceles. Let any triangle be ABC. Produce BC to X, making $AC=CX$; produce AC to Y, making $BC=CY$. Draw AX and BY. In triangle ACX, $\angle X=\angle CAX$; in triangle BCY, $\angle Y=\angle CBY$. $\angle ACB=\angle X+\angle CAX=\angle Y+\angle CBY$. Also $\angle X=\angle Y=\angle CAX=\angle CBY=1/2\angle C$. Applying the law of sines to triangles BAX and BAY

$$\frac{BX}{AB}=\frac{BC+CX}{AB}=\frac{BC+AC}{AB}=\frac{\sin(A+CAX)}{\sin X}=\frac{\sin(A+\frac{1}{2}C)}{\sin\frac{1}{2}C}$$

$$\frac{AY}{AB}=\frac{AC+CY}{AB}=\frac{AC+BC}{AB}=\frac{\sin(B+CBY)}{\sin Y}=\frac{\sin(B+\frac{1}{2}C)}{\sin\frac{1}{2}C}.$$

The third ratio in each of the above being identical, we may equate the last two ratios, from which $A+1/2C=B+1/2C$ hence $A=B$.

As a final example, I shall give a proof for trisecting an angle by use of straight edge and compass. This proof was presented by a senior student in high school, who laid no claim to originality, but said he could not see why mathematicians had worried over the problem so long, if it was that simple. The construction *is* simple, and can be carried out by anyone. The proof can be followed by most students before they have had a semester of plane geometry.

Let the given angle be XBC. On the side BX, lay off any convenient distance BA. Bisect BA at M, draw MK parallel BC and ML perpendicular BC. On the straight edge, mark two points, P', Q', at a distance BA apart. Now pass the straight edge through B, so that P' lies on MK and Q' on ML. Mark the points thus located P, Q. Then the line BP trisects the angle.

The proof is outlined as follows: $\angle PBC = \angle BPM$. Take N, the midpoint of PQ and draw NM. Then N is equidistant from P, Q, M, being the midpoint of the hypotenuse. $\angle ABN = \angle BNM$ also $\angle BPM = \angle PMN$. The exterior angle $BNM = \angle BPM + \angle PMN = 2\angle BPM$. Hence $1/2\angle ABN = \angle PBC$ and we have $\angle PBC$ is one-third of the original angle.

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A LECTURE DEMONSTRATION OF THE LEAD CHAMBER PROCESS

BY LOUIS R. WELCH

Dorchester High School for Boys, Dorchester, Massachusetts

Sulfuric acid is produced in the lead chamber process by the reactions between sulfur dioxide, the oxides of nitrogen, steam, and air. High school textbooks give a detailed description of the commercial sulfuric acid plant. The following demonstration experiment, emphasizing the chemical reactions involved, serves as an aid in vitalizing this description.

A few drops of concentrated nitric acid are poured into a two liter acid bottle. The bottle is rotated in a horizontal position until the inside is thoroughly moistened. If the bottle is now heated gently the brown fumes of nitrogen dioxide appearing in the bottle show that the acid has decomposed to produce the oxides of nitrogen. A delivery tube from a sulfur dioxide generator is now run into the acid bottle and sulfur dioxide is allowed to mix with its contents. The sulfur dioxide can be prepared by the action of hydrochloric acid on sodium sulfite or by heating sulfur flowers in a retort. The latter method follows the commercial process more strictly, but the action of an acid on a sulfite is a more convenient method of preparing this gas in the laboratory.

The sulfur dioxide on mixing with the oxides of nitrogen pro-

duces the derivative of sulfuric acid known as nitrosyl sulfuric acid. The structural formula for this acid: $\begin{matrix}NO{-}O\\ HO\end{matrix}\!\!>\!S\!\begin{matrix}{=}O\\ {=}O\end{matrix}$ shows that it differs in composition from sulfuric acid: $\begin{matrix}HO\\ HO\end{matrix}\!\!>\!S\!\begin{matrix}{=}O\\ {=}O\end{matrix}$ simply by containing the univalent radical NO (known as the nitrosyl group) in place of one of the H atoms of sulfuric acid. As the action in the acid bottle progresses the brown fumes of nitrogen dioxide disappear and white crystals of nitrosyl-sulfuric acid, known as chamber crystals, appear on the bottom and sides of the bottle. The equation: $2SO_2+NO+NO_2+H_2O+O_2\rightarrow 2\begin{matrix}NO{-}O\\ HO\end{matrix}\!\!>\!SO_2$ represents the formation of these crystals.

The sulfur dioxide generator is now disconnected and water is added which reacts with the chamber crystals to produce sulfuric acid and the oxides of nitrogen according to the following equation: $\begin{matrix}NO{-}O\\ HO\end{matrix}\!\!>\!SO_2+H_2O\rightarrow 2H_2SO_4+NO+NO_2$. The reappearance of the brown fumes of nitrogen dioxide demonstrates the presence of these oxides. The liquid remaining in the bottle is tested with litmus solution to prove that it is an acid and with barium chloride solution to prove that it is sulfuric acid.

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FOREST COVER RETAINS OVER 99 PER CENT OF RAINFALL

The marked effect that vegetative cover has on surface run-off of rainfall was shown in recent experiments at the Holly Springs, Miss., branch station of the Southern Forest Experiment Station, U. S. Forest Service. During a 70-day winter period 27 inches of rain fell, of which 62 per cent ran off the surface of a cultivated corn field and 54 per cent off the barren soil of an abandoned field. In contrast to this enormous run-off, less than one-half of 1 per cent of the rainfall ran off the ground surface of a virgin oak forest and off an unburned native grass plot, and only 2 per cent ran off a scrub oak covered plot. The run-off from the corn field carried with it soil at the rate of 34 tons per acre.—*Science Service.*

DOUBLE CLASSES IN SCIENCE AND MATHEMATICS

By H. K. Moore
Thomas A. Edison School, Cleveland, Ohio

No doubt many science and mathematics teachers have found themselves assigned to double or at least much larger classes in science and mathematics this year due to curtailed school budgets. It appears now that many more will be holding classes of from 50 to 100 pupils while formerly they taught only 25 or 30. Perhaps the first thing that a teacher of a double class realizes is that the ordinary techniques do not apply to the larger class. A plan that worked with a small class will not usually be suitable for an auditorium class.

When this teacher of a double class tries to go to the professional literature on methods of teaching for help in his new problem he finds at once that nearly everything has been written with small classes in mind. It is up to him to devise his own techniques. There are too many in the class for old techniques and the auditorium-type room is not suited to pupil activity and discussion. He dreads to use the discredited lecture method. What then can he do? The purpose of this paper is to present one method in science and one method in mathematics which have been tried over a reasonable period of time and have been found to work.

AUDITORIUM CLASSES IN SCIENCE

The ability of pupils to achieve in large classes has been demonstrated by various investigators. There is no need to review their findings here. Nevertheless the opportunities of the child to experience the delights of success are important. His ability to see, hear, read and comprehend are items which must be taken into account in any determination of methods. In the techniques presented below this has been constantly kept in mind.

The movement away from pupil individual experimentation and toward teacher or pupil demonstrations fits in very well with the auditorium science program. In the small class individual experiments waste time and material. In the large class they are impossible. The first part of the period may well include demonstrations of those scientific principles which ordinarily would require pupil individual experiments.

In case a demonstration is not suitable for a certain day visual materials may well be used. In a series of lessons on aviation the teacher made lantern slides to illustrate the work. Ordinary window glass was cut into glass plates 3 1/4″×4″. A china-marking pencil was used to make drawings upon the glass for coarser work. In the case of detailed drawings the plate was first coated with glue and india ink used on the dried glue surface. Other visual aids are movies, charts, models, and blackboard diagrams. Thus the first part of the period consists of seeing and hearing.

The teacher who plans the second part of the lesson may well take a page from the individual instruction technique. In the series of aviation units it was decided to let the worksheet serve as the guarantee of understanding. The upper part of the worksheet is devoted to a summary of the demonstrations, teacher explanation and visual material. Then follow questions on the summary. The pupil-scores on the worksheet give the teacher an excellent hint as to what is or is not clear to the class or to the individuals who compose the class. Here is a sample worksheet from the aviation series:

Unit 8. Control Surfaces

An automobile needs only to be equipped with steering gear for turning to the right or left. A boat is equipped with a rudder for the same purpose. The airplane needs to be controlled for three things. To control sideways tipping the airplane has an aileron on each wing. To govern the up and down movements of the airplane there are elevators on each side of the rudder at the tail. To determine the direction of flight the plane has a rudder.

The rudder is governed by a bar pivoted in the center of the floor and operated by the feet. The ailerons and elevators have a common control known as the Joyce stick or "joy stick." This stick can be moved in any direction because it is mounted on a ball joint much as a gear shift lever on an auto. Because the air is not a solid support and because of air currents the three controls must be constantly moved in order to keep the ship flying level.

Because it requires great effort to move the rudder and other control surfaces against the wind they have been put on hinges and balanced so that the wind helps to move them.

Questions: Using the information just given write in the answers to the following questions:

1. How many controls are needed by the auto for determining direction?
....
2. How many are needed by the airplane?..........................
3. What controls the sideways tipping?............................
4. What controls the up and down direction?.......................

5. What controls the right and left direction? . . . .
6. Upon what are the ailerons mounted? . . . .
7. What lever controls the ailerons? . . . .
8. What lever controls the elevators? . . . .
9. What lever controls the rudder? . . . .
10. Why are airplanes equipped with balanced rudders? . . . .

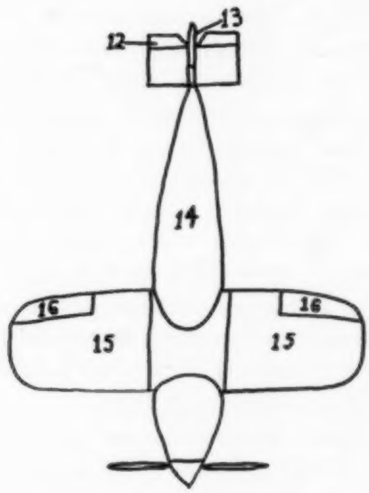
. . . .

11. What two control surfaces are moved by the Joyce stick? . . . .

. . . .

Write in the names of the numbered parts

12. . . . .
13. . . . .
14. . . . .
15. . . . .
16. . . . .



. . . .

cut off

. . . .

Answers: 1. one. 2. three. 3. ailerons. 4. elevators. 5. rudder. 6. wings. 7 & 8. Joyce or joy stick. 9. rudder bar. 10. to make it easier to move the rudder against the wind. 11. ailerons & elevators. 12. elevator. 13. rudder. 14. fuselage. 15. wing. 16. aileron.

The answers are cut on the same stencil as the worksheet but are cut off the printed papers. These answers are passed out at the end of the period so that the papers may be corrected.

Since all pupils will not complete the worksheet at the same time it is necessary for the teacher to provide supplementary material for the faster workers. This may consist of an interesting chapter on the subject studied or the drawing of an illus-

tration for a certain point. In the case of the above worksheet the reader will note that the hardest material appears last and is the only part of the worksheet for which the summary contains no answer.

AUDITORIUM MATHEMATICS CLASSES

In the case of both science and mathematics it will be advantageous to appoint pupil monitors. Often it is a good job for the class discipline problems. Their work will be to check on attendance, pass out books and other materials, and to make themselves generally useful.

In our auditorium math classes diagnostic tests were given at the beginning of the semester for the purpose of discovering individual weaknesses. Then remedial work was given for the purpose of bringing all as near as possible up to grade.

In the case of new work an adaptation of the science technique is used. The new principle is first explained and illustrated by the teacher. Then the class proceeds to work individually on the new assignment. The teacher moves about the class giving individual help *while* they are working and *while* they are having their troubles. When more widely adopted this should probably prove a boon to those parents who often have to teach their children those things which the teacher has not made clear.

Whenever possible the marking of papers is taken care of by the class. A child needs to know what mistakes he has made as soon as possible after he makes them.

A minimum of subject matter is set up for the whole class. Then those who can do more are given work beyond the minimum. Each child climbs just as fast up the ladder as he is able.

This paper has not attempted to go into the advantages and disadvantages of the auditorium class. It has assumed that the auditorium class is a situation to be met. The aim has been to salvage as many of the advantages of the small class as possible and to add to these certain advantages of the large class. The result is an interesting experiment in mass education.

A glance at the bibliography will show in what respects the above methods conform to recent trends and the findings of recent experimentation.

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TOO MUCH ECONOMY IN EDUCATION

From an address by Hon. Harold L. Ickes, *Secretary of the Interior*

I do not deny that of necessity some economies must be made in our schools. But we are going too far in that direction. Our schools ought to be the last to feel the pinch of economy, just as they ought first to experience the return of prosperity. Undoubtedly the educational tree needs some pruning. There may be some dead and decayed branches that ought to be cut off. But if such pruning is necessary it should be done scientifically, by experts. It serves no good purpose of economy and it is immensely damaging to our educational system to slash into a budget regardless of whether we are cutting into a vital spot or not.

Even in these days of tremendously pressing problems, to my mind the most important question of all is, what are we going to do about our schools. That education should be universal goes without saying. By education I mean more than the three R's. I believe that every child should be given all the education that he can reasonably absorb. This does not mean that all children should spend an equal number of years in school or that all should take the same courses. It means that everyone in order to have the best chance possible for a happy and full life should have every bit of education that he is capable of receiving and of using to advantage.

He should have this not only for his own sake but for the good of the whole. The intelligence of a nation is the sum of the intelligences of all of its citizens. Intelligence is the product of education and education is the greatest national asset that we have. No nation in these times can hope to survive, to say nothing of progressing in the arts and the sciences, in commerce, in trade, or in industry, unless it is composed of a well educated citizenry. Least of all can a democracy, depending, as it must depend, upon an informed public opinion for the selection of its leaders and the framing of its laws hope long to endure unless it consists of a highly and universally educated electorate. The individual American must be educated not only that he may be able to enjoy a happier and fuller life; he must be educated in order that, in cooperation with other educated Americans, he may do his part toward sustaining and upbuilding an intelligent and beneficent and capable government.

FARRAR AND RINEHART, INC. EXPANDS

Farrar and Rinehart, Inc., Nine East Forty-First Street, New York, N. Y. is enlarging its activities and is establishing a College Department for the publication of college textbooks.

Mr. James E. Van Toor, who has a long record and a wide acquaintanceship in college publishing will be in charge of the new College Department.

A GEOLOGY CLUB IN A PROGRESSIVE SCHOOL—AN EXPERIMENT

By Dorothy V. N. Brooks
Massachusetts State Teachers College, Westfield, Mass.

THE PLACE OF CLUBS IN A SCHOOL PROGRAM

To satisfy the need for time to work out student initiated plans, last year the Fieldston Middle School rearranged its schedule to allow a club period on three afternoons a week. There were no requirements for membership in these clubs except the common interest which drew the leaders and pupils together for the purpose of exploring certain hobbies outside the limits of classroom time or subjects.

So enthusiastic was the reception given the club program and so varied were the demands that twenty-five clubs were scheduled. All manner of activities were represented from the extra study of languages and history to the playing of games. Thus, while one group conversed in German, another gave its earnest attention to chess, while still another explored the mysteries of puppet plays. From among those scientifically inclined four clubs were organized: physics, radio, chemistry, and geology.

THE GEOLOGY CLUB

A group of boys from eleven to thirteen years of age demanding to collect rocks and learn geology in one short hour a week presented an interesting challenge to their leader. Obviously, they wanted no books nor classroom lectures; it was "field experience" they clamored for. Their background was varied. Some already had remarkable collections made at an earlier age when to build up and own a collection of something was the dominating motive. Several had learned something of rock identification at summer camps or in Boy Scout activities. All knew the treasures to be found in the Natural History Museum, and several felt they had a personal friend in the curator who had won their confidence and stimulated their interest by the consideration with which he received each baffling specimen taken to him for identification.

With time so short and the meetings so far apart these embryo geologists were impatient with any preliminary explanations which would hold them indoors. It was field experience they demanded—and out into the field they went. The Fieldston campus

is situated on rocky ledges of Fordham gneiss between the Hudson River and the old valley followed by Broadway, in the north west corner of New York City. The gneiss varies locally in its composition and in its state of weathering, and the whole has been modified by the glacier, exposing here a smoothed and grooved expanse of rock and there a high bank of morainal material.

WEATHERING DEMONSTRATED IN THE FIELD

The blasting for a foundation nearby offered a splendid contrast between a fresh and weathered surface of the same rock, and the leader's statement that each blast uncovered rock which had never before been seen by man—that the constituents of that rock antedated man's appearance on this earth, roused the keenest interest, for the survey history course of Form I was teaching them the antiquity of the earth and the rise of primitive man. Here was a correlation that struck a sympathetic chord.

How did this fresh, hard rock, beautifully banded in shades of gray, flesh pink, black and white, ever become the deep, rich soil which supports our vegetation? The joint system was clearly marked: water had penetrated some of the crevices and discoloration had followed. Great was their excitement when they realized that the bright reddish brown color staining the face of the gray or black bands of gneiss was rust, for they had experimented in science with the changes brought about when water, air and iron work together. Here, then, was their first example of weathering.

The October nights were chill. What would happen if the water trickling down the joint cracks were to freeze? Another last year's science experiment answered their question. Across the street, on a long exposed ledge, a dogwood's roots had explored the crevices, and, growing, had wedged out large pieces of rock. Around the corner one exposure was weathered to the crumbling stage and each rain washed tiny grains of quartz and flakes of mica to the foot of the hill, there to mix with the falling leaves. Soil! Decomposition, disintegration; the most important phase of each in weathering demonstrated in situ, and a series of specimens illustrating the changes brought back to the school were the rewards of the first field trip.

GLACIATION—FROM A MORAINE

History and geography had introduced the topic of continental glaciation so that there was an excellent foundation for

another trip both on the campus and two blocks away, where a street had been cut through a deep deposit of glacial debris on bed rock. That heterogeneous material proved a font for questions as well as a mine for specimens not indigenous to the vicinity. With that bank on one hand and a glacially scoured surface within sight, their imaginations were quick to grasp the significant factors of glacial action and to visualize the glacier in its advance across the Palisades, over Manhattan, until it halted and accumulated the detritus which now forms the backbone of Long Island and the morainal hills stretching across New Jersey.

ROCK IDENTIFICATION

When cold weather drove them in doors, sufficient interest had been aroused by their out door observations and collections to make the boys desirous of learning means of identifying rocks. It was then that the generous loans of the Natural History Museum were introduced and from them they derived their first intimation of a system of classifying kinds of rocks and of a means of identification. Since they had collected a variety of specimens to which they were anxious to give names, they attacked the problem of learning the common constituent minerals, the difference between crystalline and sedimentary rocks, and the nomenclature of the classifications with an enthusiasm seldom seen in a college freshman seated before his specimen tray.

A simplified chart according to texture and composition of the more common kinds of rocks found under each of the three large classifications of igneous, sedimentary and metamorphic was developed. As each was considered, specimens from the Museum loan were compared with their as yet unidentified rocks, and gradually the miscellaneous collection took form. There were gaps, to be sure, because a gneiss foundation with a glacial moraine veneer is not the most prolific collecting ground, but the specimens were products of their own collecting and identifying experience and were, therefore, all the more valuable. And slowly these gaps were filled: a paving block provided the granite; a new building, the slate; the copestone of the window ledge, the limestone. Marble of a coarse, granular variety had been found in the neighborhood of Marble Hill. It was fragmental and discolored, but how much more prized than the pure white commercial specimen left from the

new building. Pictures and diagrams were introduced to supplement the leader's explanation of the origin of each new specimen.

TOPOGRAPHIC MAPS

Topographic maps are apt to be a maze to the uninitiated, so complicated do they seem if there be no preliminaries to unravel the facination they may hold. The suggestion that the club study contour maps was apathetically received until pleistocene in a flat bottomed glass dish was modeled into an uneven mainland, sea and island. Ways and means of showing that model on a flat surface were discussed to review their knowledge of maps, scales and methods of showing relief gained in geography. Then as water was added to the depth of one half inch at a time, representing increment elevation, each child in turn etched the contour so formed, while the leader pointed out the salient factors such as altitude, shape, grade and behavior in crossing stream beds, expressed by contour lines. The difficulties they encountered when the boys attempted to reduce that model to a contour map emphasized the more strongly the essential features of a topographic map.

When each pupil was confronted with a topographic sheet of a region with which he was familiar the conventional symbols held no fear for him because he recognized in them only a more detailed picture of what he himself had previously drawn. Neither time nor preparation permitted any interpretation of features beyond reading of simple landscape and a few observations on human adjustments to the terrain. The object of introducing them was accomplished in familiarizing the student with the maps.

THE STORY OF A BOULDER

When spring came and the group could again pursue their hobby out of doors, the goal had changed from "collecting" to collecting "good specimens," and particularly were they interested in the component minerals which were abundant in the pegmatites of the vicinity. Thus, rather than darting at any weathered stone that caught the eye, as they had done in the fall, they now searched for and carefully chiseled out good examples of quartz, mica, feldspar and the fibrous hornblende, or clambered up for a particularly good specimen of banded or contorted gneiss, the pride and zeal of the intelligent collector spurring them to improve and enlarge their exhibition.

. With eyes now trained to observe, one boy noted something unusual about the one glacial boulder of any size to be found on the campus and his find proved to be one which was prized above all others. It was an irregular block of New Jersey arkose: coarse grains of milky quartz in which were imbedded large, angular pink feldspar and rose quartz pebbles. It was only another rock until the group gathered around it one afternoon while the leader traced the history which those angular pieces of feldspar told of the short trip from the parent rock to their new position as scree. Rapidly the succeeding steps were sketched in as the Triassic sedimentaries were formed. The climax of the drama came with the next transportation, this time with the glacier as agent instead of gravity and water, to its present position on the campus. For weeks afterward the young geologists were to be seen taking their classmates to the scene and explaining the dramatic story held by that drab boulder for the initiated.

THE RE-DISCOVERY OF THE PALISADES

The plea for a longer trip, where something different could be found, was answered by the excursion across the Hudson River to the Palisades Inter-State Park. With increased knowledge came increased tolerance of preliminary explanations and a good foundation for a field study of sedimentary rocks had been laid in the story of the arkose boulder. There had only to be added the account of the lava flows, the tilting of the layers and the subsequent erosion creating the Palisades and Watchung Mountains, so that there was keen curiosity and lively appreciation of what was to be seen.

Most of the boys had tramped many a mile along the path at the foot of the cliff, blind to the story which nature has there unfolded for those to read who can. With their newly developed powers of observation, they were quick to note the difference in these rocks from anything they had seen, to follow the strata, to mark new layers, to see the dip, the texture, the colorings and to compare the capping diabase with the underlying sedimentaries.

Probably as surprising to them as any of their discoveries was the fact that the familiar reddish face of the Palisades, so well known to New Yorkers, was but the surface discoloration, the rusting, the decomposition in the weathering process, and that the diabase was really a dark gray rock. This self-initiated

discovery finally corrected the tendency to identify weathered specimens without exposing a fresh surface, against which the leader had struggled in vain all year. Nothing which had been said impressed them with the necessity of such a precaution until they observed that the Palisades were not red but gray. A series of weathered and unweathered igneous rocks added to their original collection demonstrating weathering, marked their comprehension of this fundamental geological rule.

THE EVALUATION OF AN EXPERIMENT

The opportunity for summarizing the broad and disconnected work of the year came in the plan for an exhibition which concluded the work of all clubs. The desire to display everything was suppressed by the limited space for display assigned each club, imposing on the pupils a careful review and organization of the knowledge which had become theirs. It was to their credit that they rejected the temptation to focus on the loaned specimens of unusual or beautiful minerals, which would have attracted all of their attention a few months earlier, in preference to an orderly arrangement of the common rocks with terse explanations of means of identification and occurrence. "Why everybody will want to know how to tell what they see every day. Ours will be the best exhibit of them all," exclaimed one enthusiast.

The increasing enthusiasm evinced by the boys as the year progressed gave abundant proof of the genuine stimulation of interest they had experienced. Theirs was not a superficial coating of information which would send them on secure in a smug assumption that they had skimmed the cream from geology. They had learned to use the primary tools of their science in the simple system of classification, the means of identification of rocks, and in topographic map reading. It was in the intelligent use of these tools that they realized how much more lay in wait for them in the rich mine of geology. But more than this they gained. The opportunity for correlation of their hobby with their academic subjects emphasized the aim of education as a whole rather than by segregated units, and this gain in perspective is of immeasurable value. Every subject made its contribution: world history told of man's development on earth and of the glacial advances; geography had prepared the way for map study; the science course was called upon constantly to explain various phenomena; and mathematics in-

terpreted the surveyor's use of angles in making contour maps. Assuredly the benefits accruing to the individuals, as well as the pleasure derived by the students and leader alike in the fellowship of a common hobby, removed the geology club from the ranks of an experimental activity to one of proven educational value.

WHY SOME STUDENTS DO NOT ELECT CHEMISTRY

By Cliff Otto
Central State Teachers College, Edmond, Oklahoma

Much has been said and written about why one should study chemistry. The information in this article was gathered in an effort to determine why some students do not study chemistry.

The data were taken over a period of twelve months from senior students in a state teachers college. A previous study (1) had shown that approximately one-half of the graduates of the institution have studied chemistry either in high school, college or both. The study was not made in an effort to load the chemistry classes with students as the entire science department of the institution has all the student load it can carry. It was only a sincere effort to get the mental slant of the student who graduates without getting acquainted with the important field of chemistry.

No Pandemic Chemistry or courses of that nature are offered in this college. All science work is held rather strictly to standard courses that are accepted for credit in any institution to which the student may desire to transfer his work. It has long been realized that science enrollment could be increased by offering the so-called popular courses. However, there is one great objection to them from the standpoint of teacher training. Should the student fill up his college requirements with courses of that nature, there would be no way to keep him from going out and accepting a science teaching position in some high school. The ability of such courses to equip anyone to teach any science in high schools is questionable.

The writer had, through the course of a year, an opportunity to contact senior students in groups. Careful explanation of the information desired was given and a special effort made to see that each student wrote his own personal sentiment in answer to the following question, "Why have you not studied any

chemistry in college?" A total of 371 replies was received. The reports were made in writing in secret. No student was permitted to sign the reply as absolute freedom in answering was desired. A study of the answers indicated that the students had responded in each case to the preliminary preparation by making truthful and carefully considered responses. The tabulation of the answers is shown in table No. 1.

TABLE No. 1

Results of 371 replies to question, "Why have you not studied any chemistry in college?"

1. Can not do the mathematics	14
2. Too expensive	18
3. Too much time required for laboratory	45
4. Too difficult	72
5. Not interested and do not care for it	63
6. Can not use it in (student's) work	41
7. It is not required	18
8. Have to take too many required subjects	23
9. Do not like the instructors	6
10. Chemistry is not useful or practical	3
11. Have had no foundation for it	9
12. Work required is out of proportion to other subjects	6
13. Afraid of laboratory experiments	1
14. Not interested in and do not like any science	20
15. Laboratory odors make (student) ill	2
16. Make too low grades in chemistry	6
17. Not worth the effort and time required	3
18. Prefer some other science	9
19. Have not received proper educational guidance	12
20. Too dumb to learn it	3
Total	371

CONCLUSIONS

1. There are some valid reasons for a student's not studying chemistry.

2. The outstanding feature of the replies was the general lack of any expressed desire for well rounded knowledge, development of personal capacity through individual effort, or interest in the nature of the world in which we live.

3. The students showed rather definitely that they know what they are trying to do. Many of them are taking the easiest route toward graduation and a license to teach and frankly admit it. Whether or not one likes their methods, the definiteness of their objectives must be admitted.

4. Faulty mathematical preparation is very common.

5. Numerous students are not able to take full advantage of their college opportunities due to lack of funds.

6. No doubt some successful chemistry students are lost through lack of understanding of the nature of the work, finances and other reasons.

7. The principal reason why students avoid chemistry is because it is a man's size subject and they do not care to put out what it takes to master it.

1. Otto and Inlow, SCHOOL SCIENCE AND MATHEMATICS, vol. 30, No. 3 (1930).

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INTEGRAPHS

By Conrad K. Rizer
New York City

In higher mathematics it is necessary to make calculations which take, not minutes or hours, but weeks, months, or even years. In order to speed up such work scientists at different times have invented machines to do the work for them in much less time. The calculators, such as banks have, are not very expensive in relation to the work they do. However in higher mathematics, machines have been constructed to make very elaborate calculations and express the answer in the form of a graph instead of figures. A calculator of this sort is often too specialized and too expensive to be made commercially.

In calculus, integral curves may be produced mechanically from differential or coefficient curves by such instruments as integraphs. The field of integral equations is too complex for any one instrument to handle all types. On the other hand, any given problem requires usually but one instrument, which, for reasons of expense and ease of obtaining, may be built preferably in one's own work-shop rather than found in a dealer's display case. Even if a single machine would draw any integral curve, its cost and bulk might cause it to be a curiosity rather than an aid. The place of the complex, expensive integraph, as the one lately developed at the Massachusetts Institute of Technology, is in the field not covered by the simpler types.

It is intended here to review briefly the literature on integraphs that have not been placed in the hands of manufacturers to market. All of them, except the one just previously referred to, are inexpensive. The functions of some overlap. The instrument may be able to draw differential curves as well as integral, depending on whether the given curve is considered integral or differential.

In 1881, about the time Abdank-Abakanowicz made known his instrument which he later turned over to G. Coradi of Zurich to make and sell, Professor C. V. Boys described his development[1] before the Physical Society of London. Each man had worked independently of the other on his project. Professor Boys's integraph will integrate ydx, y^2dx, y^3dx, as well as dx/y which solves such problems as the time occupied by a body in moving along a path when the law of the velocity at different

parts is known. It may also be made to integrate the product of two or more functions, but is not designed to differentiate.

On the eve of the present century, M. Michel Petrovitch, Professor of Mathematics at Belgrade, devised an hydraulic integraph[2] which would solve first order differential equations. The idea involved is ingenious and interesting to study, but it is not so practical as those of other designs which cover the same equations. Also, it is not suited to differentiation.

The three elliptic integrals were the cause of A. F. Ravenshear, in 1915, building an apparatus[3] which would describe any one of them in rectangular coördinates, the value of the integral between the assigned limits being found by the measurements of the ordinates of the graph. The integrals are dealt with in the Legendre form. The third elliptic integral, which occurs frequently in electrical engineering and hydrodynamics, makes this instrument useful to many. Diagrams and pictures accompany the description of the apparatus and its operation. This, of course, is not an integraph as usually defined, for the only curve concerned is the integral curve which is dependent on the adjustment of the mechanical set-up.

Two years later Armin Elmendorf published a design of an integraph[4] based on the "movable center" sphere device, discovered by Professor Hele-Shaw, 1884. By duplicating the sphere *n* times, an integral of the *n*th degree may be had from a given differential equation. It is suited to tracing problems of work, distance, and velocity, to determining stresses and deflections in beams and girders in structural engineering, and to finding centers of gravity and moments of inertia of masses having irregular surfaces.

During the study of "hunting" current surges of synchronous machinery around 1920, Vladimir Karapetoff, Professor of Electrical Engineering at Cornell, realized what a boon an integraph would be in determining the size of a fly-wheel, a calculation which requires a double integration of the tangential effort curve. He evolved such a calculator[5] based on parallel double tongs. An integral or differential curve of any degree may be found for any given curve. The integral curve of one tracing becomes the differential curve of the next tracing, or vice versa. From the parallel double tongs design, Professor Karapetoff developed a double integraph[6] which will solve linear partial differential equations with constant coefficients, as in problems of transient electric phenomena in telephone and power lines.

Construction details are found in the article referred to and in references listed in it. The practical capacities of the two integraphs of Professor Karapetoff have a direct appeal to those who are in the throes of problems solvable with these instruments.

The latest development comes from the Massachusetts Institute of Technology, where Dr. Vannevar Bush, Professor of Electrical Power Transmission, and his co-laborers have expressed the integraph[7] in super terms. The basis of construction is the electrical integrating watthour meter, combined with a moving table. The given curves to be followed by indices are the coefficients. Variable discontinuities or multiple valued coefficients are handled as well as less complex coefficients. Errors of the machine are of the order of one per cent for common use. The order of the equations solvable is limited only by the number of units employed. This instrument is adapted to the solution of any total differential equation. The form need not be linear, nor the coefficients constant. It is adapted to such problems as those of continuous beams, electrical machine behavior, vibrations in mechanical structures, ballistics, stability analysis, and electrical circuit relationships, especially with non-linear elements such as rectifiers or thermionic tubes. However, it will not do problems of fields of force and flow, the aerofoil, the hydraulic turbine, and the resistance of a ship. As Professor Bush points out, the inherent expense of this design will prohibit many from being built, but it does command the attention of engineering centers.

Another integraph[8] brought forth by M.I.T. is a photoelectric one which is capable of evaluating an integral having a variable parameter. The light of the optical system is limited by apertures having the shape of the area under curves representing mathematical functions. The accuracy obtainable depends upon the problem involved as well as the care used, but is of the order of 2 to 5 per cent.

1. Phil. Mag., Ser. 5, vol. 11, p. 342 (1881).
2. Phil. Mag., Ser. 5, vol. 49, p. 487 (1900).
3. Proc. of Phys. Soc. of London, vol. 28, p. 81 (1915).
4. Wisconsin Engineer, vol. 21, p. 314 (1917).
5. Jour. Opt. Soc. Amer. & Rev. Sci. Insts., vol. 6, p. 978 (1922).
6. Cornell Univ., College of Eng. Experimental Station. Bull. No. 4, (1925).
7. Tech. Eng. News, vol. 9, p. 52 (1928).
8. J. Franklin Inst., 212, 77–102, July, 1931.

A BEGINNER'S JUSTIFICATION FOR THE VECTOR ADDITION OF ANGULAR VELOCITIES

By Earl L. Mickelson
New Mexico State Teachers College, Silver City

INTRODUCTION

First-course college text-books in physics introduce the scheme of representing the angular velocity of a particle about an axis by a vector laid off along the axis of revolution. The length of the vector represents the magnitude of the angular velocity and the direction of the vector is that in which a right-handed screw would advance if twirled in the sense that the particle revolves. The books then go on to say that angular velocity vectors may be combined and resolved just as force vectors, linear velocity vectors, and other vectors may be so manipulated. No justification for the assertion is offered, however, and little attempt is made to picture the simultaneous revolution of a body about two axes, no statement is made as to whether or not the axes are supposed to remain fixed, no statement is made as to whether or not the velocities are supposed to be instantaneous.

The present paper gives a partial justification for the assertion that angular velocity vectors may be combined and resolved according to the parallelogram law. The justification consists of showing by means of elementary geometry that in two simple cases the transverse components (i.e., components mutually perpendicular to their respective axes and radii of revolution) of the linear velocities of a particle due to the corresponding angular velocities of the particle combine vectorially. The demonstration of this fact provides a picture for the simultaneous revolution of the particle about two fixed intersecting axes.

In what follows angular velocities will be designated by the capital letter Ω and linear velocities by the capital letter V; the magnitudes of these vectors will be denoted by the small letters ω and v, respectively.

MOTION IN A CIRCLE

To begin with, consider a particle P revolving in a circle of radius r with an angular velocity of ω radians per unit time about the center O. Let V be the instantaneous linear velocity

when P is in the position shown in Fig. 1. Since the motion is in a circle, the vector V is perpendicular (transverse) to the radius at P. Let PM and PN be any two mutually perpendicular directions through P and let V' and V'' be the components of V along these directions, respectively. Through O draw a line parallel to PM, intersecting PN produced at a point N', and call the distances ON' and $N'P$ by r'' and r', respectively. From the similar triangles in the figure it follows that $v'/v = r'/r$ so

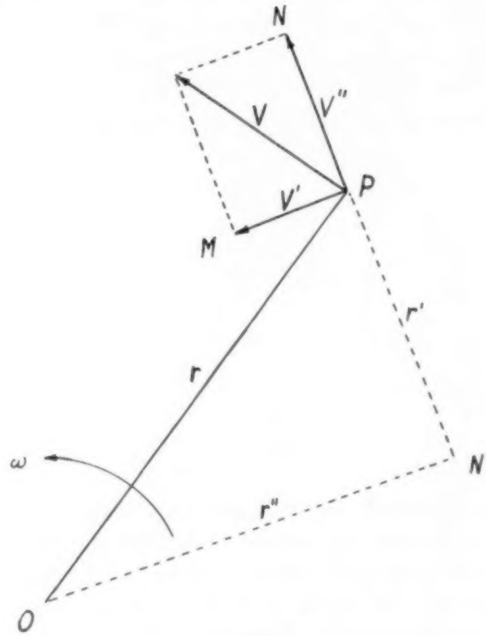


FIG. 1

that $v'r = vr'$. But by the definition of a radian $v = \omega r$. Therefore, $v'r = \omega r'r$, from which it follows that $v' = \omega r'$. In a similar manner it can be shown that $v'' = \omega r''$.

FIRST SIMPLE CASE

Suppose now that a material particle P is revolving about a line OJ with an angular velocity of ω radians per unit time which is represented by the vector Ω laid off along OJ according to the usual convention. Let OI and OK be any two directions through O such that both these directions and the line OJ all lie in the same plane. Resolve the vector Ω along these two directions into the components Ω_1 and Ω_2. The assertion to be

partially justified is that P is moving in such a way that Ω_1 and Ω_2 represent its angular velocities about the directions OI and OK, respectively.

For this first simple case consider the situation at the instant that P is in the plane of the vectors (See Fig. 2): Drop perpendiculars from P to the sides of the parallelogram and to diagonal OJ and call the lengths of the instantaneous radii of revolution by r, r_1, and r_2. The transverse linear velocity of P perpendicular to the plane of the paper due to Ω is ωr downward, that due to Ω_1 is $\omega_1 r_1$ also downward, and that due to Ω_2 is $\omega_2 r_2$ upward. If the assertion given in the texts is correct then it must be true that $\omega r = \omega_1 r_1 - \omega_2 r_2$. That this statement is correct can be seen from the following elementary proof: The product

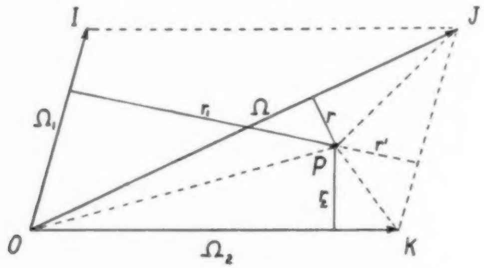


FIG. 2

ωr, geometrically considered, suggests an area. Therefore, draw the lines PO, PK, and PJ and let r' denote the prolongation of r_1 from P to the side KJ. Then ωr is twice the area of the triangle OPJ, $\omega_1 r'$ is twice that of KJP, and $\omega_1(r_1+r')$ is the area of the entire parallelogram. Consequently,

$$\omega r + \omega_2 r_2 + \omega_1 r' = \omega_1(r_1 + r') = \omega_1 r_1 + \omega_1 r'$$

whence it follows that $\omega r = \omega_1 r_1 - \omega_2 r_2$, q.e.d.

A demonstration similar to that just given can be framed for the case in which the particle P lies outside the parallelogram of vectors.

SECOND SIMPLE CASE

Consider the next most general case in which the vectors Ω, Ω_1, and Ω_2 all lie in the same plane, say, the horizontal plane, but at the instant under consideration P is not in the plane of the vectors (See Fig. 3). As before, let r, r_1, and r_2 be the perpendiculars dropped from P to the vectors Ω, Ω_1, and Ω_2, respec-

tively, and let Q, M, and N be the feet of these perpendiculars. Let O be the foot of the perpendicular dropped from P to the plane of the vectors. Let V, V_1, and V_2 be the transverse linear velocities due to the angular velocities Ω, Ω_1, and Ω_2, respectively.

By application of Fig. 1 to triangle OQP the component of V along the line OP is a vector of magnitude $\omega(QO)$ directed upward. Similarly, the components of V_1 and V_2 along OP are

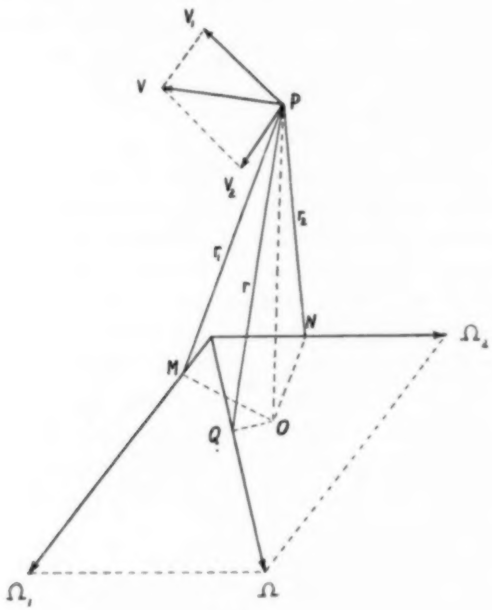


FIG. 3

vectors of magnitude $\omega_1(MO)$ directed upward and $\omega_2(NO)$ directed downward, respectively. These components, however, are the transverse linear velocities of a particle situated at O, which situation has already been cared for in the first simple case. Therefore, the vertical component of V is the resultant of the vertical components of V_1 and V_2.

Next, by Fig. 1, again, the horizontal component of V is a vector having the direction of OQ and the magnitude $\omega(OP)$, that of V_1 is a vector in the direction of OM with magnitude $\omega_1(OP)$, and that of V_2 is a vector in the direction of NO and with the magnitude $\omega_2(OP)$. These directions, however, are precisely the directions obtained by rotating the three original hor-

izontal vectors Ω, Ω_1, and Ω_2 as a rigid framework through an angle of ninety degrees in the clockwise direction as seen from above. Moreover, the magnitudes of the horizontal components along these directions are proportional to ω, ω_1, and ω_2, the magnitudes of the vectors Ω, Ω_1, and Ω_2. Consequently, the horizontal components of the linear velocities form a parallelogram with that of V as diagonal so that it is the resultant of the other two horizontal components. Therefore, since the vertical component of V is the resultant of the vertical components of V_1 and V_2 and the horizontal component of V is the resultant of the horizontal components of V_1 and V_2, it follows that V is the resultant of V_1 and V_2, q.e.d.

CONCLUSION

For more complicated cases in which, for example, the vector Ω is resolved along lines not all in the same plane, this method of presentation becomes exceedingly cumbersome. Furthermore, since no account has been taken of the components of the linear velocities other than those transverse to the radii and axes of revolution one cannot expect to clarify the picture of the motion by pursuing this demonstration further. But the point is that by means of these elementary applications of geometry one can give the student some picture of the motion which is correct as far as it goes and can partially justify the assertion that angular velocities may be combined and resolved as other vector quantities.

PROBLEM DEPARTMENT

Conducted by G. H. Jamison
State Teachers College, Kirksville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS OF PROBLEMS

Note. Persons sending in solutions and submitting problems for solution should observe the following instructions:

1. Drawings in India ink should be on a separate page from the solution.

2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

3. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

1289. *Boris Garfinkel, Buffalo, N. Y.*
1290. *Boris Garfinkel, Buffalo, N. Y.*
1283. *Merton Cuthbert, Los Angeles, Calif.*
1281. *J. O. Austin, Cowden, Ill.*

1292. *Proposed by Samuel A. Sloan, Pittsburgh, Pa.*

In the division indicated, each X represents a digit. Find the dividend and the divisor.

Solved by W. E. Buker, Leetsdale, Pa.

$$
\begin{array}{r|l}
 & XX7XX \\
\hline
XXXX7X & XX7XXXXXXX \\
 & XXXXXX = P_1 \\
 & XXXXX7X = R_1 \\
 & XXXXXXX = P_2 \\
 & \quad X7XXXX = R_2 \\
 & \quad X7XXXX = P_3 \\
 & \quad XXXXXXX = R_3 \\
 & \quad XXXX7XX = P_4 \\
 & \qquad XXXXXX = R_4 \\
 & \qquad XXXXXX = P_5
\end{array}
$$

Let d = divisor; D = dividend; Q = quotient; P_i and R_i = the quantities as shown in the figure.

(1) Since P_2, P_4 are seven-digit numbers, d must be large enough that $9d > 1{,}000{,}000$. Thus $d \geqq 111111$. Considering the 7 in d, we see that $d \geqq 111170$.

(2) $R_4 \geqq 111170$; $P_4 \geqq 1000700$. Hence, $R_3 \geqq 1011810$ (since, not counting the last digit of R_4, $R_4 + P_4 = R_3$).

(3) But, $R_2 \geqq 979999$. Hence, as $R_2 - R_3 = P_3, P_3 \leqq 878818$.

(4) Then $d \leqq 125545$ (since $d = P_3/7$). In consideration of the 7 in d, $d \leqq 125479$.

(5) As $111170 \leqq d \leqq 125479$, the fourth digit of the quotient must be 8 or 9.

(6) Suppose it is 8. Then, since $d \times 8 = P_4$, and $P_4 \geqq 1000700$, then $d \geqq 125087$. Taking account of the 7 in d, $d \geqq 125170$.

(7) d must be such that $8 \times d$ yields a 7 as the fifth digit of P_4. Trial shows that the fourth digit of d must be 4.

(8) We have, then, $125470 \leqq d \leqq 125479$. It remains to find the last digit of d. The 7's in D and R_1 require, as may be verified by trial, that $d = 125473$.

(9) Finally, $D = 7{,}375{,}428{,}413$; $Q = 58781$.

In step (6), we assumed that the fourth digit of Q was 8. If we assume the value of 9 instead, a procedure similar to the above shows that that assumption is impossible under the conditions of the problem.

1293. *Proposed by Norman Anning, University of Michigan.*

Progressions of complex numbers are mapped on Argand's diagram. When the progression is arithmetic, the points lie in a straight line. When the progression is geometric, the points lie in an equiangular spiral. What happens when the progression is harmonic?

Solved by Charles W. Trigg, Cumnock College, Los Angeles, Calif.

The general form of a harmonic progression is

$$\frac{1}{a+bi}, \quad \frac{1}{(a+c)+(b+d)i}, \quad \frac{1}{(a+2c)+(b+2d)i}, \ldots$$

This corresponds, term for term, with the arithmetic progression of which the first term is $a+bi$ and the difference $c+di$. When this A.P. is plotted on a complex plane, the points fall on a line, whose equation in terms of rectangular coordinates is,

$$\frac{y-b}{x-a}=\frac{b+d-b}{a+c-a}=\frac{d}{c}, \text{ or} \tag{1}$$

$$dx-cy=ad-bc=k. \tag{2}$$

In the A.P. any point $P=a+bi=\sqrt{a^2+b^2}(\cos\theta-i\sin\theta)$ when expressed in its trigonometric form.

The corresponding point in the H.P.,

$$Q=\frac{1}{a+bi}=\frac{1}{\sqrt{a^2+b^2}}(\cos\theta-i\sin\theta)=\frac{1}{\sqrt{a^2+b^2}}[\cos(-\theta)+i\sin(-\theta)].$$

That is, the points, Q_i, have moduli equal to the reciprocals of the moduli of P_i and amplitudes equal to the negatives of the amplitudes of P_i, which are $\tan^{-1}y/x$.

Hence the points Q_i fall on a curve

$$\begin{cases} \rho=\dfrac{1}{\sqrt{x^2+y^2}} & (3)\\[2ex] \tan\theta=-\dfrac{y}{x}\,. & (4)\end{cases}$$

From (2) and (4),

$$y=\frac{dx-k}{c}=-x\tan\theta. \tag{5}$$

From (3) and (4),

$$\rho=\frac{1}{\sqrt{x^2(1+\tan^2\theta)}}=\frac{1}{x\sec\theta} \tag{6}$$

From (5) and (6)

$$\rho=\frac{c\cos\theta+d\sin\theta}{k}\,. \tag{7}$$

Converting (7) into Cartesian coordinates

(8) $$x^2+y^2=\frac{cx+dy}{k}, \text{ or}$$

(9) $$\left(x-\frac{c}{2k}\right)^2+\left(y-\frac{d}{2k}\right)^2=\frac{c^2+d^2}{4k^2}.$$

Hence, the points of the H.P. fall on a circle, passing through the origin, with its center at $c/2(ad-bc)+di/2(ad-bc)$, and a radius equal to $\pm\sqrt{c^2+d^2}/2(ad-bc)$. Since the maximum modulus of the H.P. corresponds to the minimum modulus of the A.P. the slope of the diameter of the circle equals the negative slope of the perpendicular from the origin to the locus of the A.P.

When $c=0$, the locus of the A.P. is parallel to the Y-axis and the center of the circle of the H.P. falls on the Y-axis. When $d=0$, the A.P. is parallel to the X-axis and the center of the circle falls on the X-axis.

When $k=0$, the locus is not a circle but a straight line or a point. The specific cases are:

$ad=bc$, i.e. $a/b=c/d$; the locus of the A.P. passes through the origin and the points of the H.P. fall on a line through the origin, whose slope is the negative of that of the A.P. The case, $a+bi=0$ falls in the same category.

$c+di=0$, both the A.P. and H.P. are single points.

$a\neq 0$, $b=c=d=0$, the H.P. is a point on the X-axis.

$b\neq 0$, $a=c=d=0$, the H.P. is a point on the Y-axis.

$c\neq 0$, $b=d=0$, the H.P. falls on the X-axis.

$d\neq 0$, $a=c=0$, the H.P. falls on the Y-axis.

Also solved by Allen Andersen, Wagner College, N. Y.

1294. A solution to this problem will be offered in the next issue. EDITOR

1295. *Proposed by Edmund H. Umberger, Lebanon Valley College, Annville Pa.*

Given the rectangle $ABCD$, with AB equal to 8, BC equal to 6, and O the midpoint of AB. A semicircle with O as center and AB as diameter, is drawn *outside* the rectangle. A point P is chosen at random inside, or on, the semicircle and is jointed to O. A line perpendicular to OP at O cuts CD, or CD produced, at R. What is the chance that a line drawn perpendicular to CD at R and cutting the semicircle at S will have a point in common with the segment OP?

Solved by the Proposer

Let the x-axis lie along AB and draw the y-axis through O perpendicular to AB. Let $P(x, y)$ be a point so chosen as to lie on RS. The slope of $OP=y/x$ and the slope of $OR=-x/y$.

But, as the slope of OR also equals $6/x$, $-x/y=6/x$ or $x^2=-6y$.

Thus the path of points P which will lie on RS is a parabola dividing the semicircle into the two portions $OPTA$ and $OT'B$, and the remainder $OTVT'$. The two portions $OPTA$ and $OT'B$ contain points P which will satisfy the given condition of intersection, while the remainder $OTVT'$ contains points P which will not satisfy the given condition.

Therefore the required chance is the ratio of the sum of the areas $OPTA$ and $OT'B$ to the area of the semicircle.

The equation of the circle is $x^2+y^2=16$.

Solving the system $x^2=-6y$

$$x^2+y^2=16 \qquad \text{we find } y=-2$$

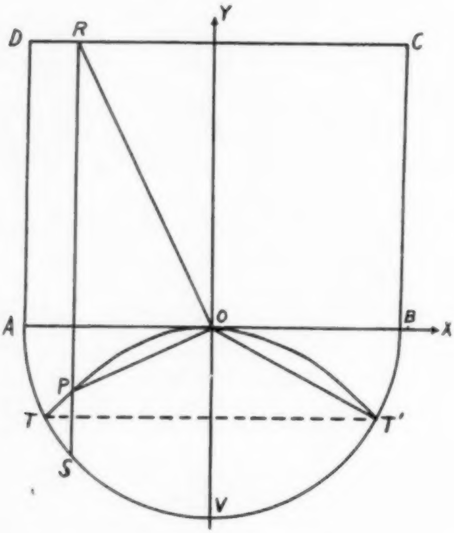
and $x = \pm 2\sqrt{3}$, this locating the points T and T'.

Area $OPTT'$ is two-thirds the area of the inscribing rectangle or $16\sqrt{3}/3$

$$\operatorname{Sin} \angle T'OV = \frac{2\sqrt{3}}{4} = \frac{\sqrt{3}}{2} \therefore \angle T'OV = 60°.$$

$$\text{Area } TSVT' = \frac{2\angle T'OV}{360}\pi\overline{OA}^2 - \frac{\overline{OA}^2 \sin \angle T'OV}{2} = \frac{16\pi}{3} - 4\sqrt{3}$$

$$\text{Area } OTVT' = \frac{16\pi}{3} - 4\sqrt{3} + \frac{16\sqrt{3}}{3} = \frac{16\pi}{3} + \frac{4\sqrt{3}}{3}.$$



The area of the semicircle is 8π.
The required chance therefore is

$$\frac{8\pi - \dfrac{16\pi + 4\sqrt{3}}{3}}{8\pi} = \frac{2\pi - \sqrt{3}}{6\pi} = 0.2414.$$

NOTE. Mr. Charles W. Trigg in his solutions points out that a necessary assumption that "*A* point *P* is chosen at random inside, or on the semicircle in such a manner that the probability that *P* will fall within an area *a* inside the semicircle is equal to the probability that will fall within any other equal area *b* within the semicircle."

1296. *Proposed by L. W. Sires, Wayland, Mo.*

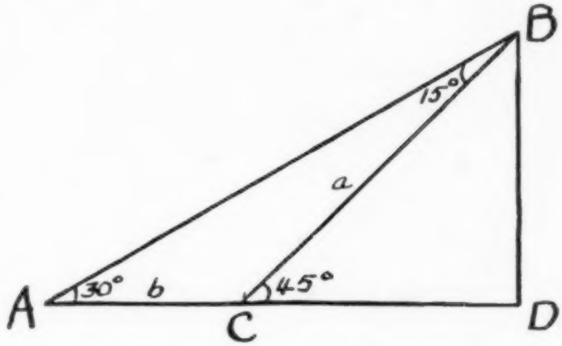
Prove $\cot 7\frac{1}{2}° = (\sqrt{3} + \sqrt{2}) \cot 22\frac{1}{2}°$.

Solved by Allen E. Andersen, Wagner College, Staten Island, N. Y.

In the figure, let $BD = 1$. Then: $CD = 1$, $AD = \sqrt{3}$, $b = AC = \sqrt{3} - 1$, $a = CB = \sqrt{2}$.

By the law of tangents we have

$$\cot 7\tfrac{1}{2}^\circ = \frac{a+b}{a-b}\cot 22\tfrac{1}{2}^\circ = \frac{\sqrt{2}+\sqrt{3}-1}{\sqrt{2}-\sqrt{3}+1}\cot 22\tfrac{1}{2}^\circ.$$



Since $(\sqrt{2}-\sqrt{3}+1)(\sqrt{2}+\sqrt{3})=(\sqrt{2}+\sqrt{3}-1)$ it follows that $\cot 7\tfrac{1}{2}^\circ=(\sqrt{2}+\sqrt{3})\cot 22\tfrac{1}{2}^\circ$.

Also solved by Charles W. Trigg, Los Angeles, Calif., W. E. Buker, Leetsdale, Pa., John E. Bellards, St. Nazianz, Wisconsin, and John W. Tarkey, New Bedford, Mass.

1297. *Proposed by R. T. McGregor, Elk Grove, Calif.*

Given the sum of the sides about a right angle and the altitude upon the hypotenuse. Construct the triangle.

Solved by John E. Bellards, St. Nazianz, Wis.

From the consideration of the figure we obtain

(1) $$m^2=a^2+(s-a)^2=s^2-2a(s-a).$$

But Area $=\tfrac{1}{2}hm=\tfrac{1}{2}a(s-a)$ or $hm=a(s-a)$ (2) Substitute (2) in (1) and we obtain

(3) $$m^2=s^2-2hm \text{ or } s^2=2hm+m^2 \text{ or } s^2=(2h+m)m$$

In order to determine m we now draw $AB=s$ and at B erect a circle tangent to AB with radius h. Draw secant from A through the center. The extended portion of the secant is m. The right triangle is now easily constructed since we have the hypotenuse and the altitude on the hypotenuse.

HIGH SCHOOL HONOR ROLL

The editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

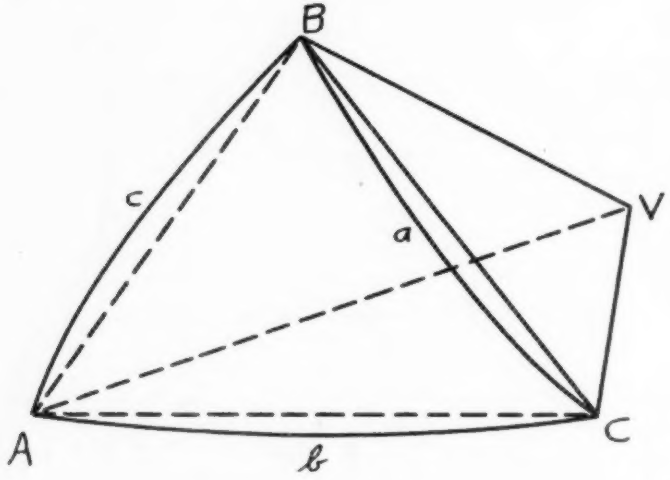
For this issue the Honor Roll appears below:

1296. Barbara Kimbrough, The Lewis and Clark High School, Spokane, Wash.

NOTE: *A solution to 1202 from the December, 1931, issue is now offered for the first time. Editor.*

1202. *Proposed by Clyde Bridger, Walla Walla, Wash.*

Find the magnitude of a trihedral angle of a regular tetrahedron. See problem 1133.



Solved by Charles W. Trigg, Cumnock College, Los Angeles, Calif.

In the regular tetrahedron $ABCV$ all of the edges are equal and all of the face angles are equal. With V as center and VA as radius construct a sphere which will pass through B and C. The faces AVB, BVC and CVA extended will cut the sphere to form the arcs c, a, and b. These arcs form the spherical triangle ABC, the spherical excess of which is the measure of the trihedral angle V.

$$a=b=c=60°.$$

$$s=\tfrac{1}{2}(a+b+c)=90°.$$

The formula of l'Huilier states that

$$\tan^2 \tfrac{1}{4}E=\tan \tfrac{1}{2}s \tan \tfrac{1}{2}(s-a) \tan \tfrac{1}{2}(s-b) \tan \tfrac{1}{2}(s-c).$$

Substituting,

$$\tan^2 \tfrac{1}{4}E=\tan 45° \tan^3 15°.$$

Solving,

$$E=31°35'5''=31.585°.$$

Since a spherical triangle is equivalent to a lune whose angle is half the spherical excess of the triangle, the triangle ABC is equivalent to a half-lune whose angle is 31.585°. Hence, the magnitude of the trihedral angle V is 31.585 spherical degrees or spherids.

The space about a point = 720 spherical degrees = 4π square radians = $129600/\pi$ or 41253 square degrees.

The magnitude of trihedral angle V may be expressed in these other units as 0.5513 square radians or 1809.7 square degrees.

Note:—This provides an alternate method of solution for problem 1133. The dihedral angles are equal. Therefore each dihedral angle $=\tfrac{1}{3}(180° +31°35'5'')=70°31'42''$.

PROBLEMS FOR SOLUTION

1310. *Proposed by W. E. Buker, Box 66, Leetsdale, Pa.*

Find the length of the shortest and longest lines from the origin to the conic $ax^2+2hxy+by^2=C$. Find also the direction of these lines.

1311. *Proposed by A. Reader.*

If S_p equals the sum of the pth powers of the first n whole numbers, $S_{15}+7S_{13}+7S_{11}+S_9=N^4$.

1312. *Proposed by Joseph Lev, Ithaca, N. Y.*

Evaluate $\sum_{n=1}^{\infty} ne^{-n}$.

1313. *Proposed by Charles W. Trigg, Cumnock College, Los Angeles, Calif.*

A polygon whose sides are a, $2a$, $3a$, $4a$, and $5a$ is inscribed in a circle. Find the area of the circle.

1314. *Proposed by Reader.*

The lines joining the opposite points of contact of a circumscribed quadrilateral are perpendicular to each other.

1315. *Proposed by George Sergent, Tampico.*

Construct a trapezoid $ABCD$, given G, intersection of non parallel sides, H, midpoint of AB, K, midpoint of AD, and E, the intersection of the diagonals.

SCIENCE QUESTIONS

December, 1933

Conducted by Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio

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Readers are invited to co-operate by proposing questions for discussion or problems for solution.

Examination papers, tests, and interesting scientific happenings are very much desired. Please enclose material in an envelope and mail to Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

"PUZZLE" QUESTIONS

622. (Repeated from June)

Your pupils are frequently puzzled by certain questions which involve simple principles only. Please send in these "puzzle" questions.

LAB. WORK "ON THE SPOT"!

635. (The Proposer asks to remain Mr. Anonymous)

Election day is close at hand in the city and voters are called upon to vote in favor of a special tax levy for the schools. Mr. Smith who has two boys in my class visits my laboratory to check on laboratory expenses among others so that he may vote intelligently.

My class is preparing oxygen by:

1. Decomposition of mercuric oxide
2. Decomposition of potassium chlorate
3. Electrolysis of water

On another day, I have them prepare nitrogen by:

1. Decomposition of ammonium nitrite
2. From air

Mr. Smith says, "Twenty years ago I graduated from college and this is the first time since I took Chemistry that I have ever heard of $KClO_3$ and NH_4NO_2. Knowledge of these two compounds and their uses in these two experiments has made no contribution to society that I can see, yet it has cost you several dollars to have your classes perform these experiments, and you even admit that they prepare them by another method commercially and also in the laboratory by the same method.

For the same amount of money as you spend in this, you could buy a barrel of crude petroleum and with the distillation apparatus you have, you could have them prepare various grades of petroleum products and get the boys interested in experimenting with the various grades of gasoline so that they can buy gasoline intelligently. Yet I am unable to find anything like this in the laboratory manual."

Question:

(a) Can you answer Mr. Smith's question in regard to the $KClO_3$ and NH_4NO_2?
(b) Can you answer his question in regard to crude petroleum?
(c) Is this laboratory procedure not the one generally followed?
(d) Is Mr Smith justified in voting against this special levy for schools when he sees many instances of this kind not only in chemistry but in many other subjects?
(e) If you can justify this procedure in the laboratory, how will you convince Mr. Smith and the voters that you are right?

636. *Proposed by the Senior Physics Class of The Norwich Free Academy Norwich, Connecticut,* Harold Geer, Secretary

Our Senior Physics Class has heard of the distinguished place of SCHOOL SCIENCE AND MATHEMATICS in High School Science; and also of your department of "Questions and Answers."

Recently a problem was brought up in our Physics class which captured our imagination. We would appreciate an expression of your opinion on this problem. It might be of interest for your "Question and Answer" department.

If from Norwich, Connecticut a twelve pound shot were dropped through the center of the earth; (a) where would it come out, and (b) what would happen to it on its journey?

PREPARING FOR MID-YEAR EXAMINATION

637. *Proposed by Mr. Carroll H. Lowe, Brookline, Mass.*

For use of Pupils in Junior Class in High School [Non-College], in Preparation for Mid-year Examination after a half year on Electricity. Boys and girls. Second half year is spent on Heating and Lighting the Home.

1. Name the magnetic metals.
2. State the laws of magnetic attraction and repulsion.
3. What was Faraday's idea of a magnetic field?
4. What is induced magnetism?
5. How is a dry cell made? Draw a diagram showing construction.
6. For maximum life, how should a dry cell be cared for?

7. Name five uses for dry cells.
8. What is the most common method of connecting dry cells? Why?
9. (a) Define the volt. (b) Define the ampere. (c) Define the ohm.
10. What four factors most affect electrical resistance?
11. State Ohm's Law and express mathematically in three ways.
12. What is the watt? How can the power in watts be computed?
13. What is an electrical circuit?
14. What is an open circuit? A closed circuit?
15. What is meant by external circuit? By internal circuit?
16. How are electrical units connected when in series?
17. How are electrical units connected when in parallel?
18. State the laws of a series circuit.
19. State the laws of a parallel circuit.
20. How can a circuit be protected against excessive currents?
21. How can we make an electromagnet?
22. Upon what things does the strength of an electromagnet depend?
23. How does reversing the current affect the polarity?
24. In what ways is an electromagnet superior to a permanent magnet?
25. Name five important uses for electromagnets.
26. Draw a diagram of a simple electric bell circuit.
27. Explain fully how the electric bell works.
28. How should three bells be connected for ringing at the same time?
29. How should several buttons be connected for ringing the same bell?
30. What instrument should be used for measuring electric current?
31. What instrument should be used for measuring electrical pressure?
32. How should each of these instruments be connected in the cirucit?
33. In what ways can we obtain an induced current?
34. State Fleming's Rule for predicting direction of induced current?
35. What important factors affect the intensity of induced E. M. F.?
36. Name the parts of the simple induction coil. Draw a diagram.
37. Explain how an induced current may be produced by a switch.
38. Name the parts of a commercial induction coil. Draw a diagram.
39. Explain the operation of a commercial induction coil.
40. Name five uses for the commercial induction coil.
41. What are the parts of an alternator (A.C. generator)?
42. What is the function of the "exciter"?
43. What factors determine the intensity of the induced current in the armature of any generator?
44. What is meant by "cycle" of alternating current?
45. What cycle A. C. is most desirable for lighting? For power?
46. How does the direct current generator differ from the alternator?
47. Explain how a split ring and brushes cause a pulsating direct current in the external circuit.
48. Name the three methods of winding the field coils of D. C. generators. Draw diagrams showing each.
49. What two machines are always required in the simple electric power plant?
50. Name three machines that may be used for driving generators.
51. How does the D. C. motor compare in construction with the D. C. generator?
52. What is the function of the commutator and brushes?
53. What two things cause a torque on the armature?
54. Why does a motor produce a back E. M. F.?
55. How do the back E. M. F.'s compare when the motor is running: (a) Fast. (b) Slowly. (c) At rest.
56. What device should be used in starting large motors? Why?

57. What are the parts of a transformer?
58. On what kind of current does a transformer operate? Why?
59. What is a transformer supposed to do?
60. Explain why we get an induced current in the output coil.
61. Write the transformer equation.
62. What are the two kinds of transformers?
63. How does the efficiency of the transformer compare with that of other machines?
64. Name five uses for transformers.
65. What is the process known as electroplating?
66. In plating with any given metal, what should we remember relative to: (a) The electrolyts? (b) The anode? (c) The cathode?
67. What kind of current should always be used for electroplating? Why?
68. What should we remember regarding pressure and current strength?
69. Name five metals that are commonly plated on various articles.
70. How can a simple storage cell be made?
71. What kind of current should be used for charging?
72. Compare direction of current during charging and discharging.
73. Write the storage battery reaction and designate where each of the products form: (a) During charging. (b) During discharging.
74. How does the commercial storage battery differ from the simple cell?
75. Name five important considerations in caring for a storage battery.
76. Name five important uses for the storage battery.
77. Explain why the specific gravity is an indication of the condition of a storage battery.
78. In what three ways can electrical energy be generated?
79. Explain the difference between positively charged, negatively charged and neutral bodies.
80. How can we obtain positive electricity by friction? Negative?
81. Explain the process of charging a body of induction.
82. What is a fixed condenser? A variable condenser?
83. What three factors determine the capacity of a condenser?
84. Draw a diagram of a simple telegraph circuit, and explain the function and operation of each part.
85. What difficulty is encountered in sending messages over long wires?
86. How can we surmount this difficulty?
87. Draw a diagram of a long distance telegraph circuit and explain the function and operation of each part.
88. Name the parts of a simple telephone circuit.
89. Describe the construction of a telephone receiver. Transmitter.
90. Explain the operation of these important parts.
91. Draw a diagram of a long distance telephone circuit.
92. Why is an induction coil necessary in the long distance circuit?
93. Explain the difference between radio frequency, audio frequency and modulated radio waves.
94. In what three ways can radio waves be set in motion?
95. Draw a diagram of the circuit for a simple crystal detector set.
96. What is the function of the crystal in such a set?
97. Draw a diagram of a three-element vacuum tube, name each part and give the name of the inventor who contributed it.
98. Draw a diagram of a single vacuum tube receiver. Show the entire circuit and explain its operation.
99. Do likewise for the simple regenerative receiver.
100. To the diagram of the preceding question add one stage of audio frequency amplification. Explain.

634. *Guild of Question Raisers and Answerers.*

NEW MEMBERS ELECTED DECEMBER, 1933

8. Clyde W. Holt, Cleveland, Ohio (Lesson Unit on Metallurgy)
9. Senior Physics Class. The Norwich Free Academy, Norwich, Conn., Harold Geer, Secretary.
10. Carroll H. Lowe, Brookline, Mass.

MEMBERS NAMED IN NOVEMBER, 1933

1. John C. Packard, Brookline, Mass.

We might appoint him "Dean of the Guild."
Then,

2. Walter E. Hauswald, Beardstown, Ill.
3. Walter C. Pribnow, Sparta, Wisconsin.
4. William W. Johnson, Cleveland, Ohio.
5. A. G. Zander, Milwaukee, Wisconsin.
6. E. W. Bemisderfer, Cleveland, Ohio.
7. William Malkin, Cloverton, Minnesota.

Your name will be added as soon as your name appears as a contributor. Please help out with new or tried ideas—questions, tests, etc.

Send in your tests and questions!!

BOOKS AND PAMPHLETS RECEIVED

The Administration of Mathematics in Secondary Schools, by Ernst R. Breslich, Associate Professor of the Teaching of Mathematics, Department of Education, The University of Chicago. Cloth. Pages vii+407. 15×22 cm. 1933. The University of Chicago Press, Chicago, Illinois. Price $3.00.

Inside the Atom, by John Langdon-Davies. Cloth. Pages ix+184. 13.5×20 cm. 1933. Harper and Brothers, 49 East 33rd Street, New York, N. Y. Price $2.00.

Molders of the American Mind, by Norman Woelfel. Cloth. Pages xii+304. 13.5×20.5 cm. 1933. Columbia University Press, 2960 Broadway, New York, N. Y. Price $3.00.

The Elements of Euclid, Edited by Isaac Todhunter with an Introduction by Sir Thomas L. Heath. Cloth. Pages xviii+298. 10.5×17 cm. 1933. E. P. Dutton and Company, Inc., 300 Fourth Avenue, New York, N. Y. Price 70 cents.

Picturesque Word Origins from Webster's New International Dictionary. Cloth. Pages vi+134. 45 Drawings. 17×25 cm. 1933. G. and C. Merriam Company, Springfield, Massachusetts. Price $1.50.

Opportunity for Investigation in Natural History, by High School Teachers. Symposium of the Biological Conference, Michigan Schoolmasters' Club, held at its sixty-eighth Meeting in Ann Arbor, April 27th to 29th, 1933. Repaged from the Journal of the Club for 1933. Paper. 127 pages. 15×23 cm. University of Michigan Press, Ann Arbor, Michigan.

The Earning Ability of Farmers Who Have Received Vocational Training. Bulletin No. 167. Agricultural Series No. 43. 44 pages. 15×23 cm. June 1933. Superintendent of Documents, Washington, D. C. Price five cents.

BOOK REVIEWS

Modern Higher Algebra, by Webster Wells, Author of a Series of Texts on Mathematics, and Walter W. Hart, Associate Professor of Mathematics, School of Education, University of Wisconsin. Pages v+410. 1933. D. C. Heath and Company, Boston. Price $1.56.

Modern Higher Algebra is a revision of the author's earlier edition. The distinguishing features of the textbook are: (1) The first seven chapters are devoted to a complete review of the first course in algebra; (2) Functional relations are emphasized in graphs, formulas, and equations; (3) Diagnostic tests are included which can be used to advantage by the teacher in motivation; (4) Mastery tests are presented at the end of each chapter for evaluating instruction and learning; (5) Cumulative reviews based on miscellaneous examples are to be used both as drills and tests; (6) Provisions are made for individual differences. Certain sections and exercises are marked by the letter "Y" or "X." Sections not so marked constitute a minimum course; sections marked by the letter "Y" constitute a preparatory course for an examination of the college entrance board; sections marked by the letter "X" provide supplementary work for capable students.

The book is well written following the simple and direct language of the earlier editions. The many friends of the Wells and Hart series will welcome this new textbook in advanced algebra.

J. S. G.

Junior Mathematics for Today, Book I, by William Betz, Vice-Principal of the East High School and Specialist in Mathematics for the Public Schools of Rochester, New York. Pages x+406. 1933. Ginn and Company, Boston. Price 88 cents.

This text is the first book in a new three-book series in mathematics for use in junior high school. It is written by a leading specialist in the field and it is a result of much experimental teaching, testing, and research. It offers a balanced presentation of arithmetic and intuitive geometry.

Special features of Book I are: (1) Arithmetical and geometric factors are presented in alternation; (2) The chapters are grouped into three principle parts: a. a preliminary study of shape, size, and position, and a review and extension of the fundamentals of arithmetic, b. the study of percentage, direct measurement, and geometric construction, c. enlarging the scope of arithmetical and geometric topics; (3) Introductory discussions at the beginning of each chapter presenting interesting materials to motivate the study of the processes and principles of the chapter; (4) Unitary organization with exercises, problems, and tests devoted to the theme of the chapter; (5) Provisions are made for individual differences; (6) A complete testing program is presented consisting of "inventory tests," "chapter tests," "mastery tests," and a "comprehensive mastery test."

The author has written the book in a very interesting manner which has a direct appeal to the pupil. The teachers of junior high school mathematics should welcome this new contribution of Mr. Betz.

J. S. G.

A First Course in Calculus, by Edwin S. Crawley and Perry A. Caris, University of Pennsylvania. Pages x×342. 1933. F. S. Crofts and Company, New York. Price $3.25.

Crawley and Caris' "A First Course in Calculus" is an introduction to the calculus presenting the classical topics usually taught in two semes-

ters. It differs in its organization from some textbooks in that the process of differentiation is treated completely through series and partial differentiation before taking up integration. The topics treated both in differential and integral calculus are well chosen and are appropriately illustrated. One feature which appeals to the reviewer is the emphasis which the authors place on hyperbolic functions, a feature which should likewise appeal to teachers of calculus in Engineering Schools.

The format is outstandingly good and the printing is especially attractive. On the whole, the book is clearly written, well arranged, logically organized, and from all indications should be teachable.

J. S. G.

College Algebra, by Joseph B. Rosenbach, and Edwin A. Whitman, Associate Professors of Mathematics, Carnegie Institute of Technology. xi+394. 1933. Ginn and Company, Boston. Price $2.00.

This new textbook in College Algebra devotes one chapter each to the following topics: Fundamental Operations, Factoring and Fractions, Exponents and Radicals, Functions and their Graphs, Equations and their Solutions, Systems of Linear Equations, Quadratic Equations, Systems of Equations Involving Quadratics, Ratio—Proportion—and Variation, Progressions, Mathematical Induction and the Binomial Theorem, Inequalities, Complex Numbers, Theory of Equations, Logarithms, Interest and Annuities, Permutations—Combinations—and Probability, Determinants, Partial Fractions, Infinite Series.

The organization and presentation of materials is traditional. However, the expositions, illustrations, and exercises are particularly adapted to the needs of the beginning student. The book abounds in carefully graded problems with answers given for the odd-numbered problems. Numerous historical references are scattered throughout the book, which associate the subject matter with its historical background. Also, an added feature of the book is, calling the attention of the student to common errors in the application of fundamental principles by means of "warnings." The book is well adapted to the needs of the student both in colleges and technical schools.

J. S. G.

Text Book of College Physics, by C. A. Chant, Professor of Astrophysics and Director of the David Dunlap Observatory, University of Toronto and E. F. Burton Head of the Department of Physics and Director of the Physical Laboratory, University of Toronto, Cloth. Pages xiv+541. 13.5×21.5 cm. 1933. Henry Holt and Company, One Park Avenue, New York, N. Y.

This is a somewhat briefer textbook of general college physics than most of the others that have appeared in recent years. It conforms in the main to the usual type. The authors recognize that the ordinary graduate of a secondary school approaches college physics with little or no knowledge of physical science. Their first care is to provide a thorough course in the elements of mechanics. This is followed by the fundamentals of the other divisions of physics, but with rather more than the normal stress on wave motion, the physics of the atmosphere, and the interference and polarization of light. It has little to say about the acoustical properties of auditoriums, emphasizes the human voice rather than musical instruments, and gives very limited attention to magnetism and to alternating currents and dynamo machinery. In general the emphasis is on physical principles rather than on their practical applications. Ample problem material is provided;

the figures are clear and well-labeled. No mathematics beyond high school algebra, geometry and the definitions of the trigonometric functions is demanded. It is a text worthy of consideration.

G. W. W.

The Story of Earth and Sky, by Carleton and Heluiz Washburne in Collaboration with Frederick Reed. Cloth. Pages x+368. 17.5×23 cm. 1933. The Century Company, 353 Fourth Avenue, New York, N. Y. Price $3.50.

This is a high class popular science book for junior high school pupils but older pupils and adults who have not had the advantages of science courses will enjoy it even though the style is particularly adapted to the experiences of children.

Part I, The Story of the Earth, gives the theory of the formation of the earth; tells the story of the formation of mountains and the work of erosion; describes the early forms of life and the evolution of higher plant and animal forms. The formation of coal, the ice age, and the appearance of man form interesting chapters

Part II, Neighbors in the Sky, is the fascinating story of the Solar System. The author takes his readers on imaginary trips to the sun and to the various members of the solar family. On these excursions many clever devices are used to show the effects of great variation in temperature, moisture, mass, etc. Among these devices are a ball game on the moon, an excursion along a Martian canal, and an attempt to chin one's self on the sun. Throughout all these stunts the author constantly reminds his audience of the difference between fact and fancy, between theory and its supporting evidence.

Part III, The Stars, is a guide to some of the principal constellations. The ancient myths and the superstitions of yesterday or even today are mingled with the latest revelations of the telescope and the spectroscope. Double stars, new stars, dark stars, star clusters, and island universes are used not merely to make a spectacular story but to present the subject matter of astronomy and inspire further study and observation.

Part IV, How We Found Out These Things, gives the story of the discovery of the laws of mechanics by Galileo and Newton under the handicap of the superstitions and religious prejudices of the times. Several chapters tell of the contributions of geology through the study of rock formations and fossil remains. The final chapters tell of the study of micro-organisms by Van Leeuwenhoek and Pasteur, and the development of the theory of evolution by Darwin.

It is a book on many phases of science, practically free from erroneous statements and misleading exaggerations, but immensely entertaining and inspiring.

G. W. W.

Inside the Atom, by John Langdon-Davies. Cloth. Pages ix+184. 13.5×20 cm. 1933. Harper and Brothers, 49 East 33rd Street, New York, N. Y. Price $2.00.

This book fills a distinct need for the Junior High School grades. It explains in simple language, and by the use of diagrams and photographs, many of the modern theories of science. It is an excellent reference book for both boys and girls. Part I deals with "Nature's Building Bricks"; Part II "Inside The Atom," and Part III "Waves." The following theories or phenomena are explained and described: Molecular Structure of Matter; Atomic Theory; Kinetic Theory of Matter and Heat; Electron Theory; Contraction and Expansion of Gases; Compression of Gases;

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Diffusion; Heat; Electricity; Sound; Light; Liquefaction of Gases; Radioactivity; X-Rays; Cathode Rays; Longitudinal Wave Theory; and Transverse Wave Theory. A simple vocabulary and simple illustrations are used to explain these theories and phenomena. The book progresses gradually from the simple to the more complex theories.

Many suggestions are offered for the construction of simple apparatus which pupils may use for observing many of the wonders of Nature. Many of the pieces of apparatus used by scientists in making their epoch making discoveries are described and suggestions made for reproducing them.

While this book is written primarily for the pupils of the Junior High School age, it cannot fail to be of interest to any person who is interested in studying science, especially the beginner.

I. C. D.

Heat and Its Workings, by Morton Mott Smith, Author of This Mechanical World. Illustrated. Cloth. Pages x+239. 12.5×19 cm. 1933. D. Appleton and Company, 35 West 32nd Street, New York, N. Y. Price $2.00.

In this little book the author has attempted to give the reader some ideas of the fundamental principles and applications of the subject of heat. This book is not intended to be used as a textbook but it is so arranged that the topics are discussed in logical sequence. The book is well illustrated with numerous pen drawings and the language is easily comprehended by a reader acquainted with high-school physics. The first few chapters deal with some of the sensations of heat, the means of detection, measurement, physical significance, and the laws which govern heat phenomena. The following chapters discuss the physical results of heat, such as the change of state, evaporation, effects of pressure, triple point, high pressures, solutions and real gases. The last chapter is more theoretical, giving some of the modern ideas concerning radiation and a discussion of the laws which appear to govern some of the modern physics. Throughout the entire book the author has traced in non-technical language the development of the subject, and has endeavored to impress upon the reader the importance of the various historical events which have influenced the progress of knowledge of thermodynamics.

LOWELL C. WARNER

TEACHERS OF SCIENCE—PROGRAM

ARRANGED BY THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE COMMITTEE ON THE PLACE OF SCIENCE IN EDUCATION DECEMBER 29, 1933

MORNING SESSION
9:30 A.M.

Massachusetts Institute of Technology
Cambridge, Mass.

Presiding Officer: E. S. Obourn, Teacher of Science, John Burroughs School, St. Louis, Missouri.

Remarks on the Committee on the Place of Science in Education and its Function in organizing the program of this Conference. Otis W. Caldwell, Chairman of the A.A.A.S. Committee on the Place of Science in Education.

Reports of Experiments in Teaching Scientific Method: Speaker's accept-

ance for above paper not yet received. Discussion led by Homer W. LeSourd, Teacher of Physics, Milton Academy, Milton, Mass.; and a teacher of science in a secondary school to be selected. Open discussion.

The Science Teacher's Scholarship and Professional Training: Wilhelm Segerblom, Teacher of Chemistry, Phillips Exeter Academy, Exeter, New Hampshire. Discussion led by Ralph C. Bean, President, New England Biological Association; and Francis T. Spaulding, Department of Secondary Education, Graduate School of Education, Harvard University, Cambridge, Mass. Open discussion.

Experiments With High School Science Clubs: Morris Meister, Chairman of the Department of Physical Science, Haaren High School, New York, New York.

Science Clubs in Relation to State Academies of Science: S. W. Bilsing, Department of Entomology, Agricultural and Mechanical College of Texas, College Station, Texas. Discussion of preceding papers on science clubs led by Pauline Beery Mack, Editor, Science Leaflets, State College of Pennsylvania, State College, Pennsylvania.

LUNCHEON
12:30 P.M.
Massachusetts Institute of Technology
Walker Memorial—North Dining Room

Presiding Officer: Jerome Isenbarger, Teacher of Biology, Chicago Public High Schools, Chicago, Illinois.

Some Reactions of Science Upon Those Who Study It: John C. Merriam, President, Carnegie Institution of Washington, Washington, D. C.

AFTERNOON SESSION
2:00 P.M.
Massachusetts Institute of Technology

Presiding Officer: H. A. Carpenter, Specialist in Science, Rochester Public Schools, Rochester, New York.

The Work of the Central Association of the Science and Mathematics Teachers: W. F. Roecker, Teacher of Science, Boys' Technical High School, Milwaukee, Wisconsin.

Types of Useful Organizations of Science Teachers: W. L. Eikenberry, Head of Science Department, State Teachers College, Trenton, New Jersey.

Are Further Organizations of Science Teachers Needed? An open discussion.

OTIS W. CALDWELL, *Chairman*	JEROME ISENBARGER
KARL T. COMPTON	BURTON E. LIVINGSTON
E. R. HEDRICK	MORRIS MEISTER

ELEPHANTS IN AFRICA BOTHERED BY MAIL PLANES

Stories of the fabled Roc, the great bird of the Arabian Nights, that could pick up an elephant as a hawk picks up a hen, are recalled by the present plight of African elephants, which are very much annoyed by the overhead rush of airmail planes.

Capt. R. J. D. Salmon, acting game warden for the Nairobi district, reports that the huge beasts' dislike of the noise of the motors has changed their habits completely, and caused them to seek new feeding grounds to north and south of their former range. This in turn has brought some of them into contact with cultivated areas where they have done much damage in native gardens.